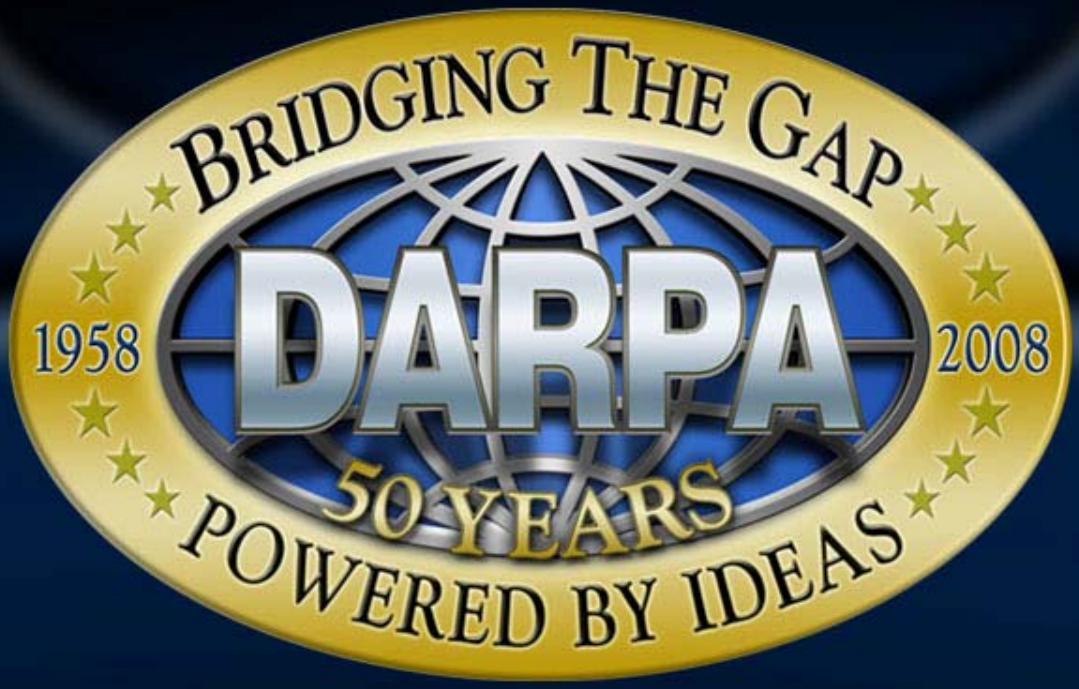

Defense Advanced Research Projects Agency

"Bridging the Gap"

Dr. Robert F. Leheny
Deputy Director

Report Documentation Page

Form Approved
OMB No. 0704-0188

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14. ABSTRACT

15. SUBJECT TERMS

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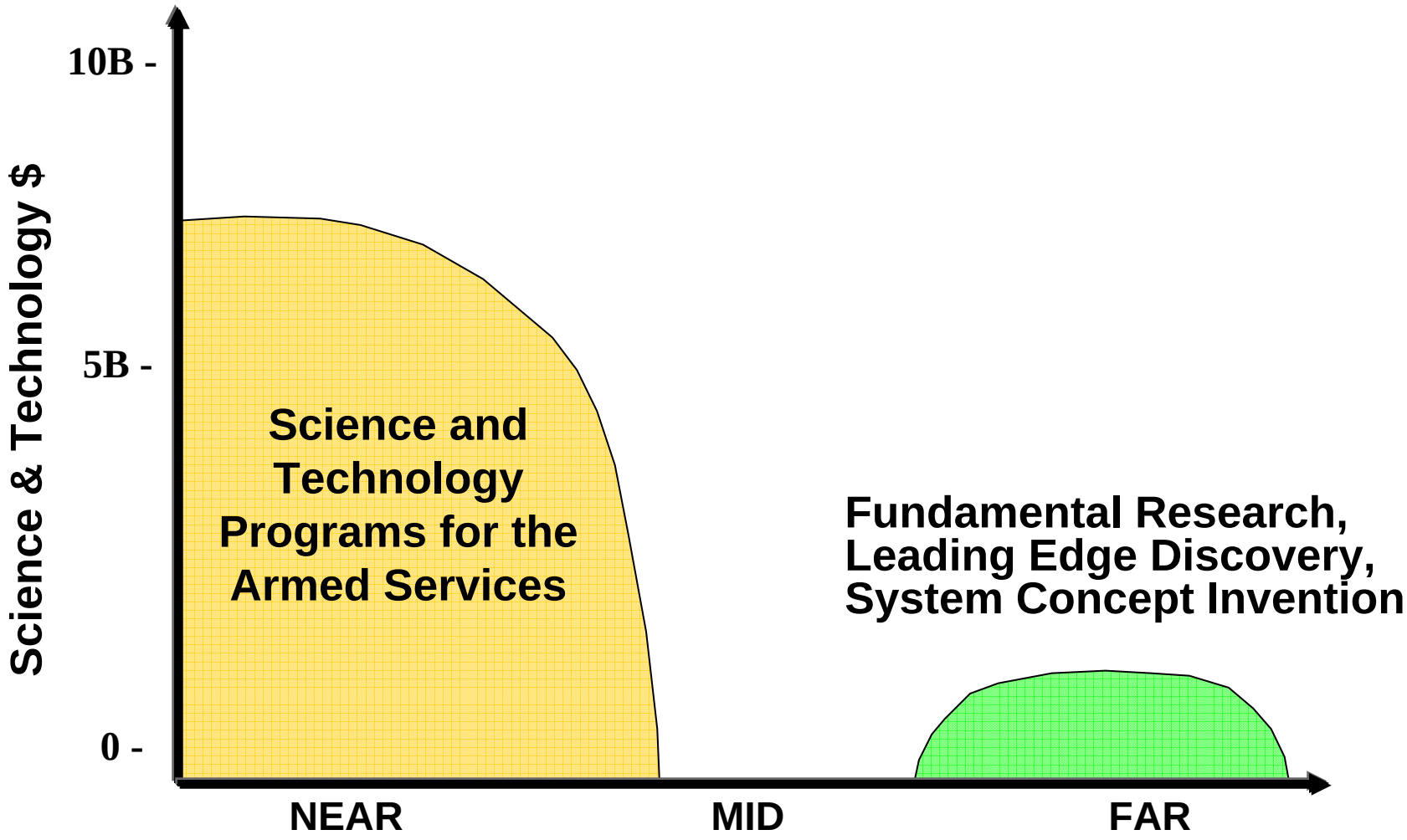
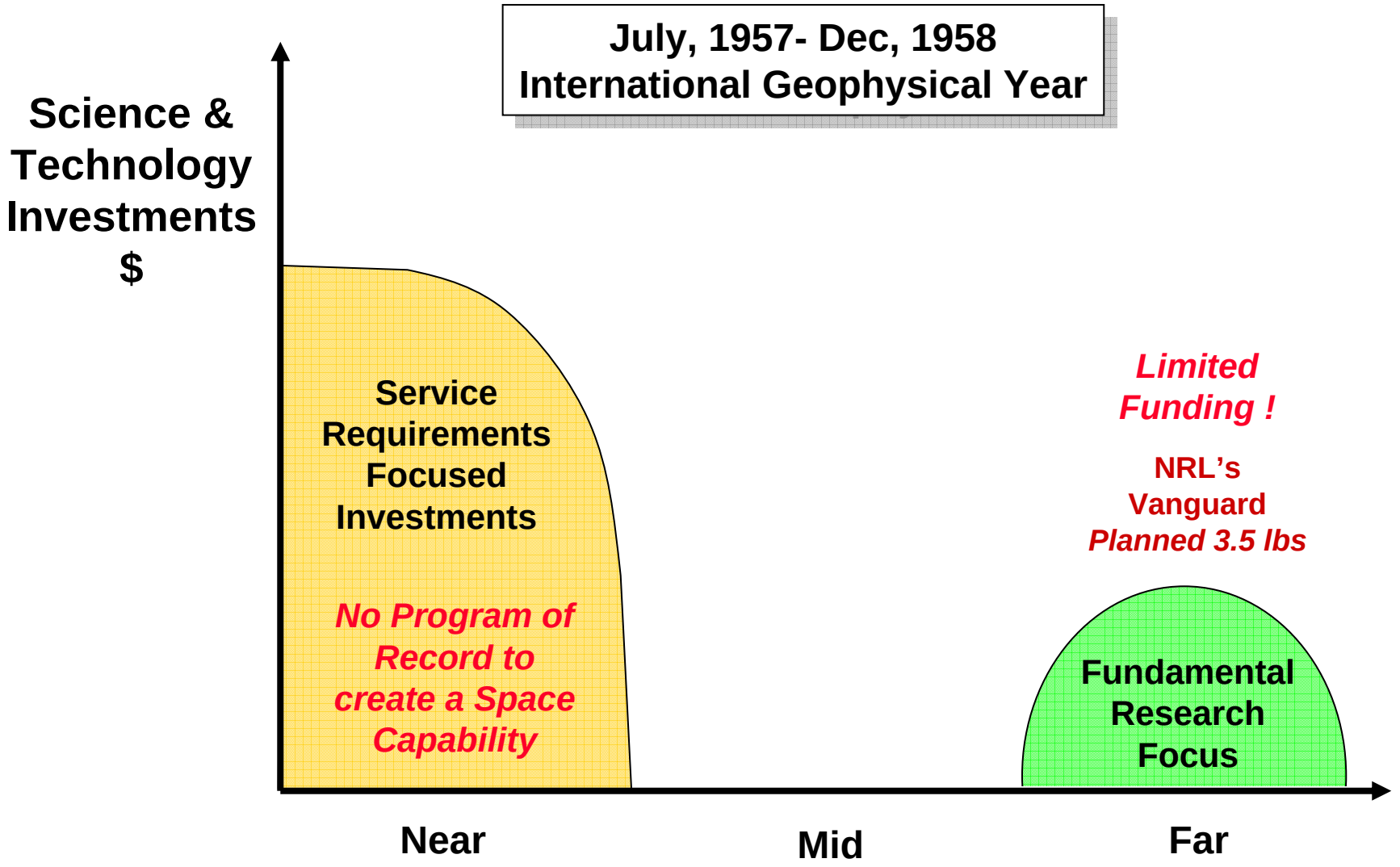
DARPA Role in Science and Technology



DOD Investments in Science & Technology
(circa 1957)



DOD Investments in S&T

Sputnik- A wake-up call

'What was that?'
Cartoon reaction to Sputnik I.
Courtesy Thomas Flannery, Baltimore Sun.

- **Sputnik- 1 Oct 1957 186 lbs**
- **Sputnik- 2 Nov 1957 1120 lbs (live dog payload)**
- **Sputnik- 3 May 1958 3000 lbs (1,327 lbs payload)**

Science & Technology Investments $

No Program of Record to create a Space Capability

Limited Money !

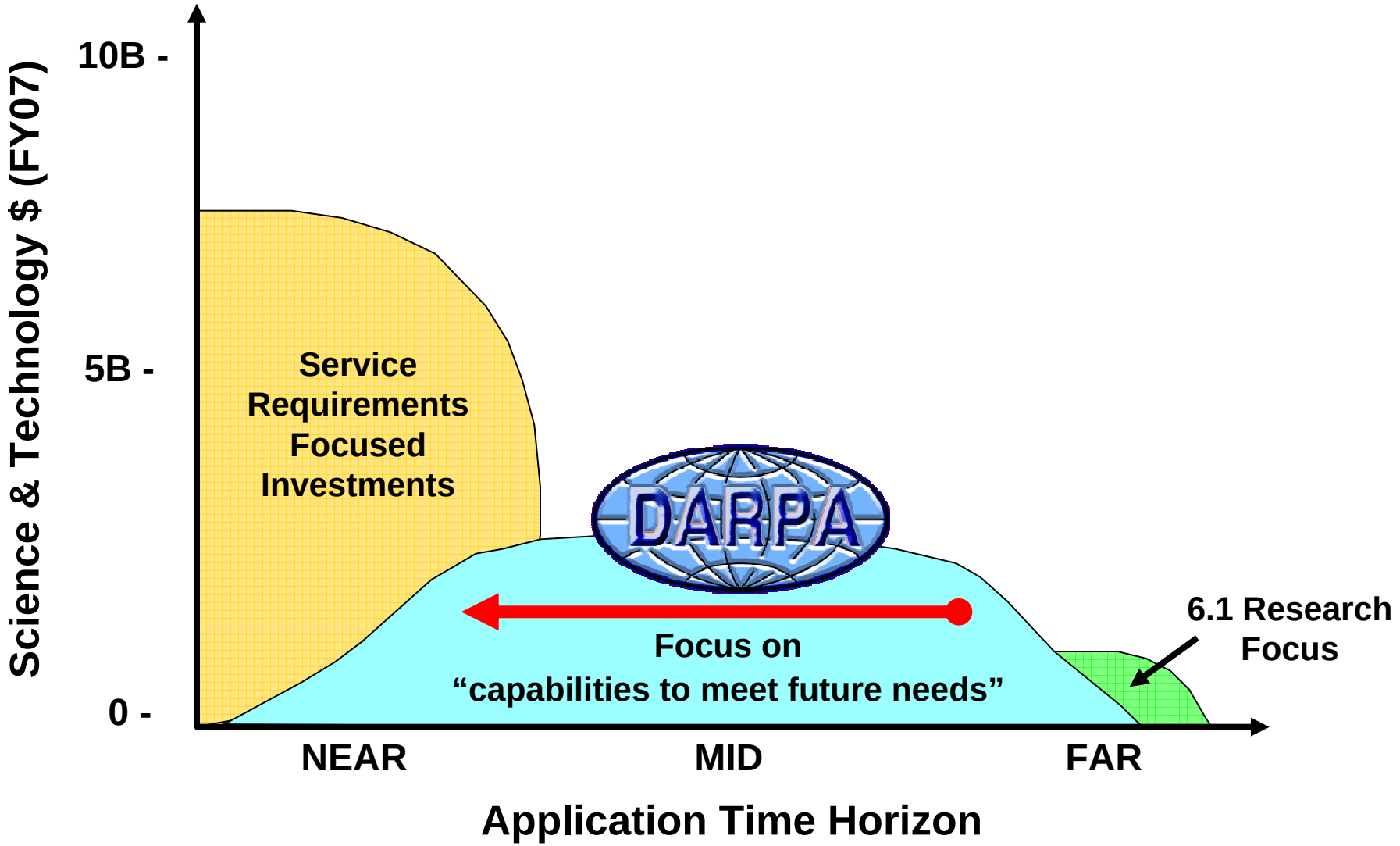
NRL's Vanguard
Planned 3.5 lbs

Near **Mid** **Far**

Time to Market

DARPA Investments:

Innovation Driving New Capabilities



DARPA Investments:

Innovation Driving New Capabilities

ARPA Responds
(August 15, 1958)

30 December 1957
Saturn I first proposed. Von Braun produces 'Proposal for a National Integrated Missile and Space Vehicle Development Plan'. First mention of 1,500,000 lbf booster (Saturn I)

29 July 1958
ARPA gives Von Braun team contract to develop Saturn I (called 'cluster's last stand' due to design concept)

15 August 1958 ARPA launches Saturn I project ARPA provided the Army Ordnance Missile Command (AOMC) with authority and initial funding to develop the Juno V (later named Saturn launch vehicle.

Go/NoGo- a Rocket with the largest Payload Capability possible

7

Science & Technology $ (FY06)

10B -

5B -

0 -

Pres. Kennedy commits US to send a man to the moon

DARPA

Focused on
"capabilities to meet future needs"

6.1 Research Focus

NEAR MID FAR

Application Time Horizon

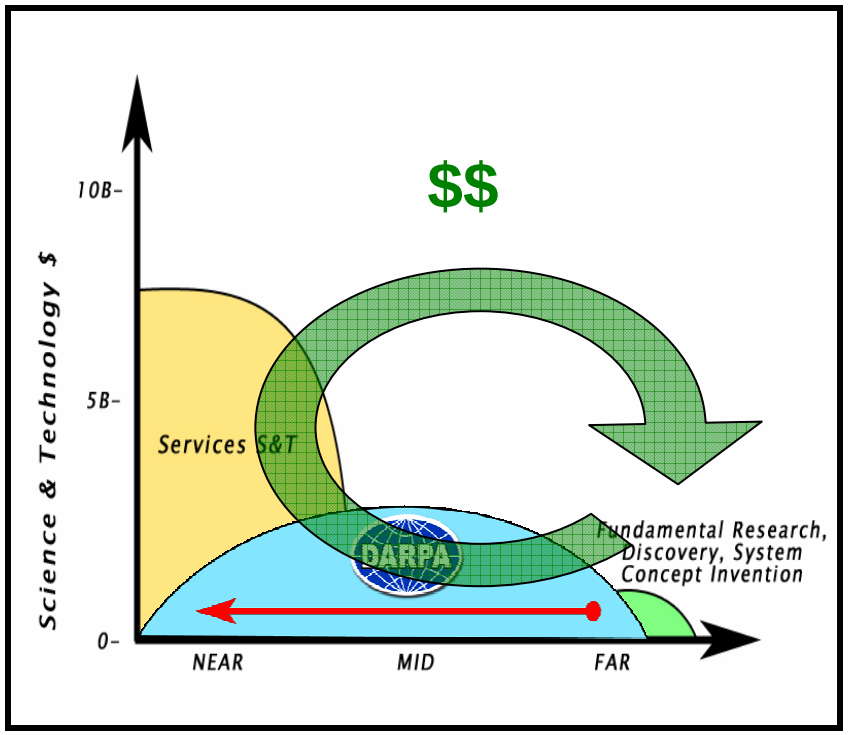
DARPA Accomplishments

DARPA Business Model

Projects (Programs) agency:

Typical projects are 3-5 years with multiple contracts-

- **Projects are phased,**
  - **Well-defined milestones (Go-NoGo) for progression between phases.**
  - **Timing of Go/No-Go decisions are dependent upon effort and not pre-determined**
- **Projects with fieldable prototypes as deliverables typically require MOUs with operators (end users) to go forward to final phase.**
- **Funding in any technology area beyond end of project contract dependent on ideas**



DARPA Organization

Director, Tony Tether
Deputy Director, Bob Leheny

Tactical Technology
Steve Welby
Steve Walker

- Air/Space/Land/Sea Platforms
- Unmanned Systems
- Space Operations
- Laser Systems
- Precision Strike

Information Exploitation
Bob Tenney
Mark Davis

- Sensors
- Exploitation Systems
- Command & Control

Strategic Technology
Dave Honey
Larry Stotts/Brian Pierce

- Space Sensors/Structures
- Strategic & Tactical Networks
- Information Assurance
- Underground Facility Detection & Characterization
- Chem/Bio Defense
- Maritime Operations

Defense Sciences
Brett Giroir
Barbara McQuiston

- Physical Sciences
- Materials
- Biology
- Mathematics
- Human Effectiveness
- Bio Warfare Defense

Information Processing Technology
Charlie Holland
Barbara Yoon

- Cognitive Systems
- High Productivity Computing Systems
- Language Translation

Microsystems Technology
John Zolper
Dean Collins

- Electronics
- Photonics
- MEMS
- Algorithms
- Integrated Microsystems

DARPA's New Initiative Process

Phase I

- Evaluate "Go / No Go" Accomplishment

Phase II

- Continue Development
- Solicit Partnership & Transition Path

Contract

Source Selection

- Evaluate Reponses
- Select Performers

Broad Agency Announcement

- Establish "Go / No Go" Criteria
- Approve Broad Agency Announcement (BAA)

Feasibility Study

Ideas

Individuals from:

- Industry
- Universities
- Entrepreneurs
- Government

DARPA Program Manager

DARPA Office Director

DARPA's Strategic Thrusts

Investments Today Create Future Capabilities

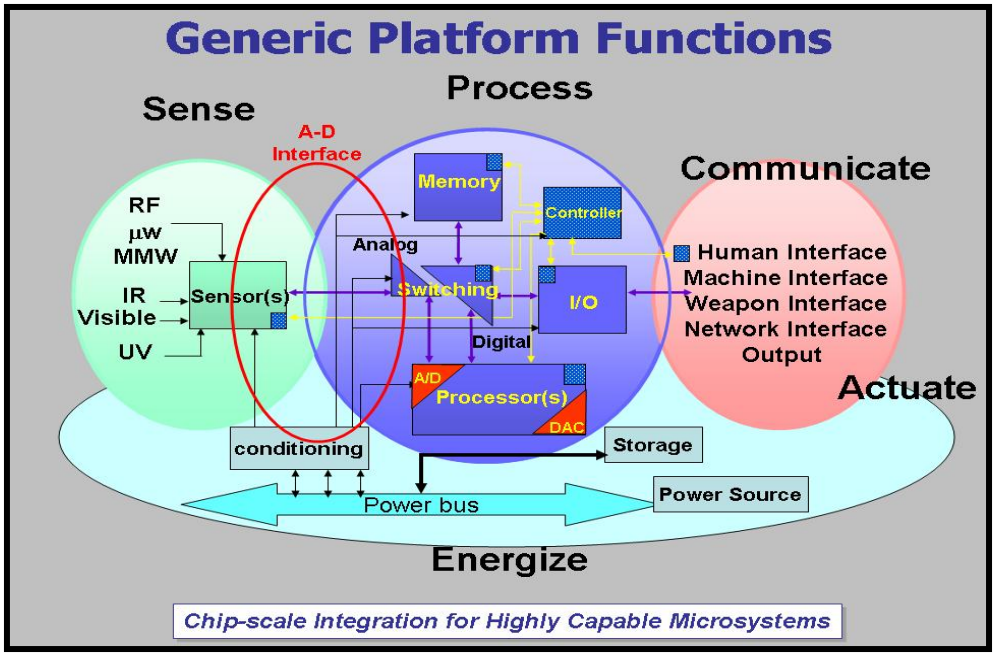
- Detection, Precision ID, Tracking & Destruction of Elusive Targets
- Networked Manned & Unmanned Systems
- Robust, Secure Self-Forming Tactical Networks
- Urban Area Operations
- Location and Characterization of Underground Structures
- Assured Use of Space
- Cognitive Systems
- Bio-Revolution
- Core Technologies (Biology / Materials / Electronics / IT)

Future Icons

- Low-cost titanium to enable routine use ($3.5/lb military grade alloy)
- Accelerate Development & Production of Therapeutics & Vaccines from 12+ yrs to 12 wks
- Alternative Energy Sources – Jet Fuel from plants
- Prosthetics to enable return to units without loss of capability
- Networks - Self-forming, Robust, Self-defending
- Chip Scale Atomic Clock to replace reliance on GPS time signal
- Networked Sensors – Determine, track, and neutralize elusive threats
- Real time language translation to replace linguists (Defense Language Institute, III → IV)
- High-productivity computing system – peta scale computer
- Air Vehicles - Fast Access, long loiter for military operations
- High Energy Liquid Laser Area Defense System as a penetration aid to replace stealth
- Space capabilities to enable global military operations
- Grand Challenge – Accelerated development of autonomous ground vehicle technology

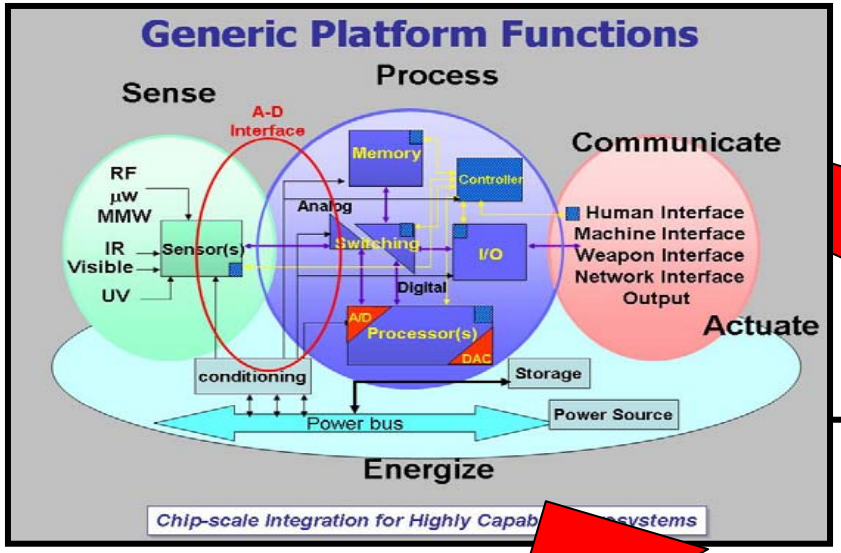
Opportunities

Microsystems Technology Advances
Enable Future ICONS



- Sense
- Process
- Communicate
- Actuate
- Energize

Opportunities

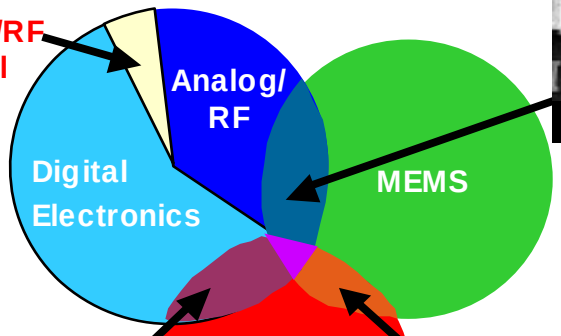


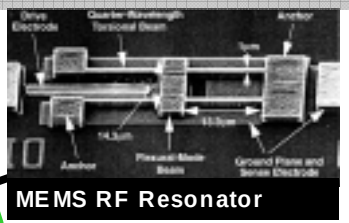
Applications Create Challenges

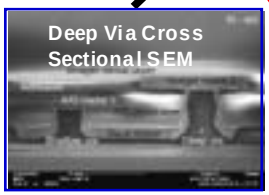
Innovations Create Capabilities

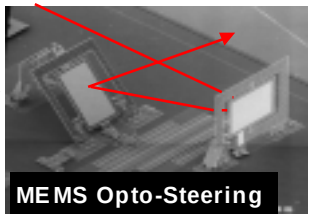
Core Technologies

Digital-Analog/RF Mixed Signal

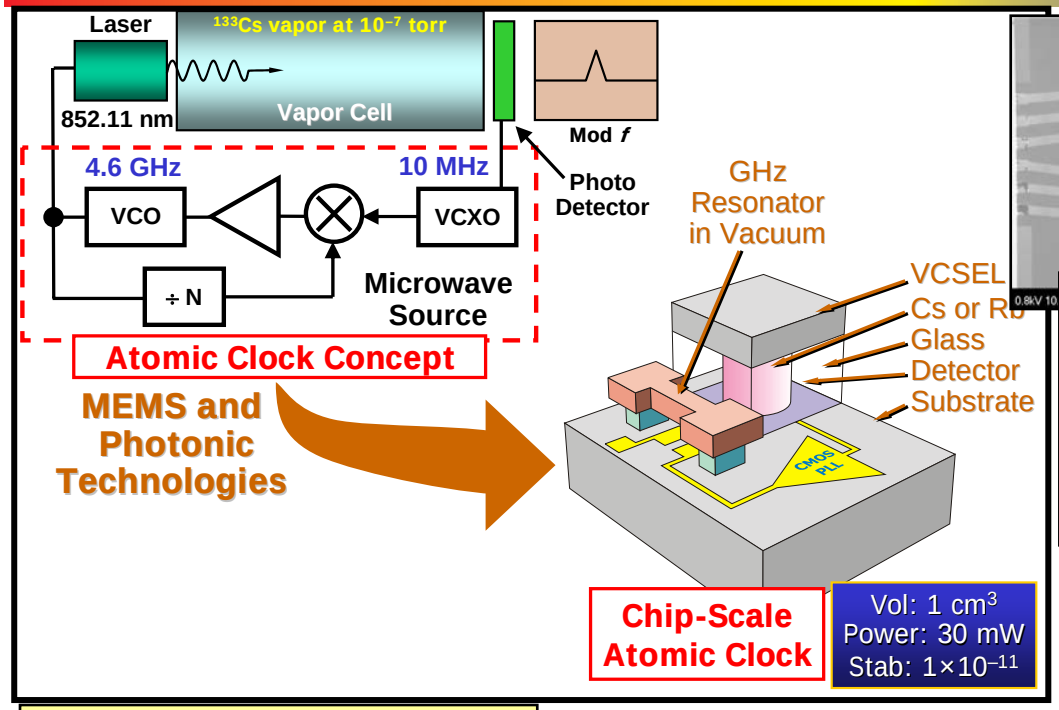


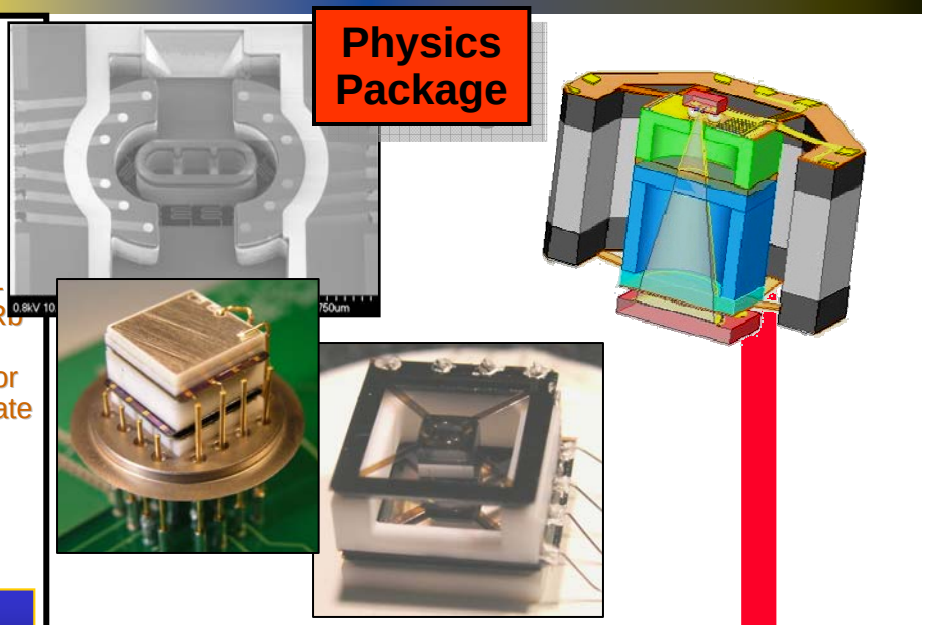


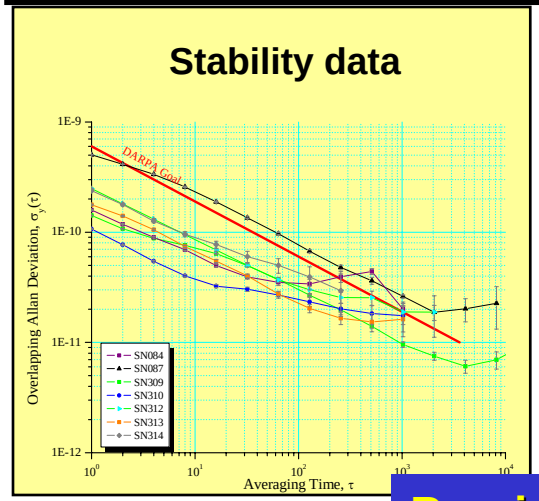




Chip-Scale Atomic Clock

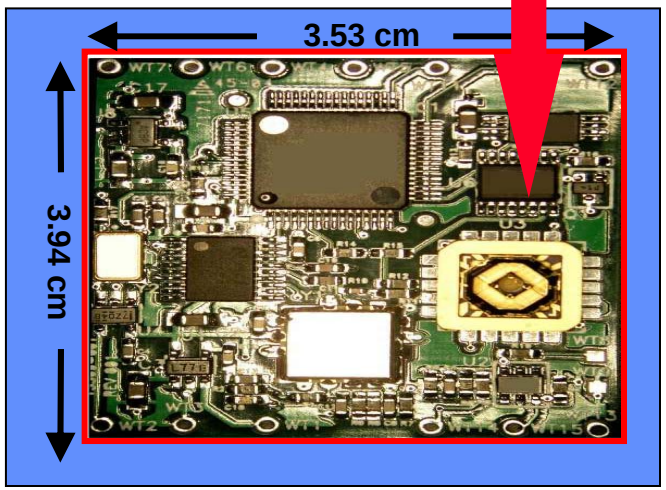






Goal:
Miniature, low-power atomic timing and frequency references with

- **Allan deviation < 10^{-11} over 1 hour (1μs/day)**
- **Size <1 cc**
- **Power Consumption < 30 mW**



Precision Time for Every Radio and Network Node

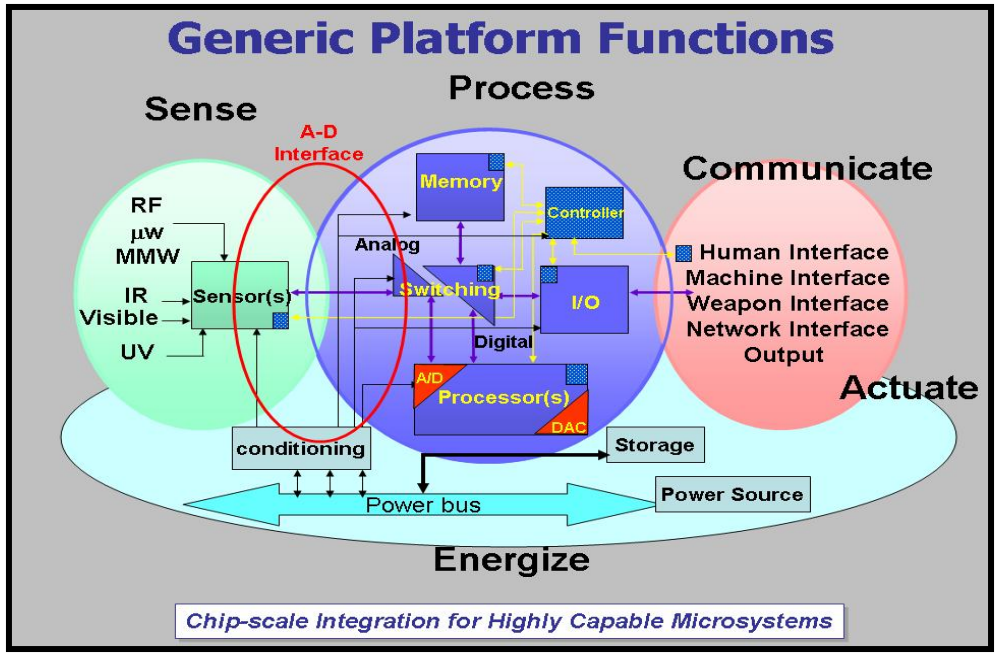
WASP – Hand Launched UAV

- 2 Color video cameras & GPS
- Weigh: 13 oz.
- Endurance: 30-40 min
- Speed: 20-34 knots

- Hand Launched
- Autonomous Flight
- Auto-Navigation
- Auto-Land

Opportunities

Microsystems Technology Advances
Enable Future ICONS



- **Sense**
- Process
- Communicate
- Actuate
- Energize

Sense

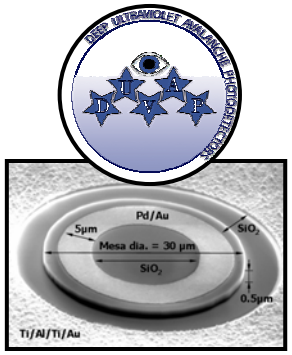
Focal Plane Arrays

SHORT-WAVE

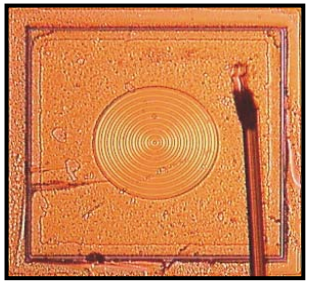
MEDIUM-WAVE

LONG-WAVE

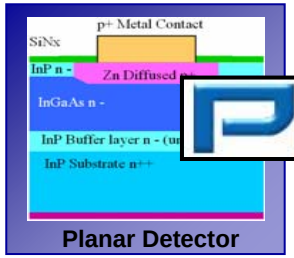
THz



DUVAP
(0.5 μm)

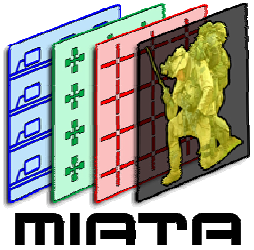


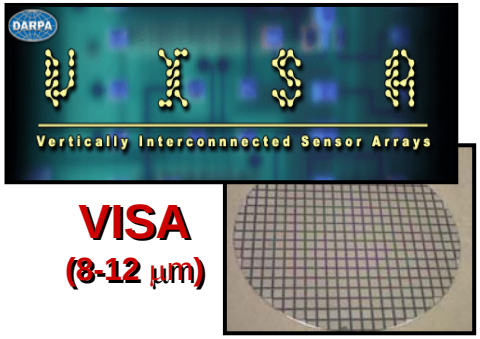
HOT-MWIR
(3-5 μm)



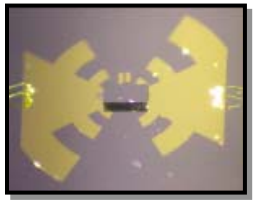
PCAR
(1-2 μm)

(8-12 μm)

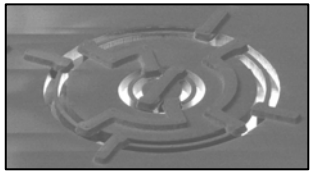




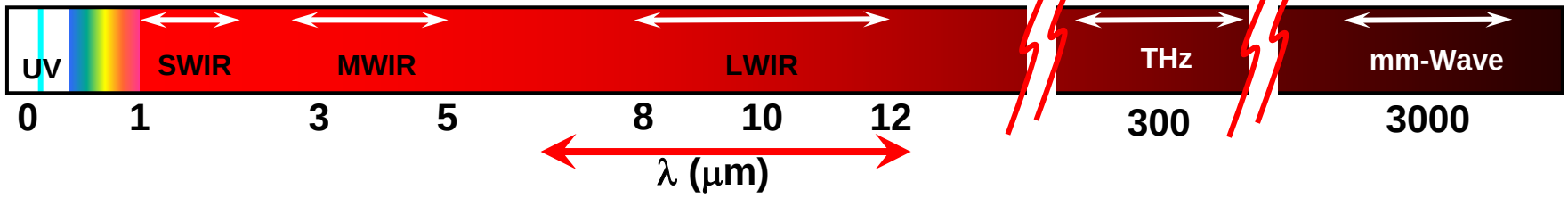
VISA
(8-12 μm)



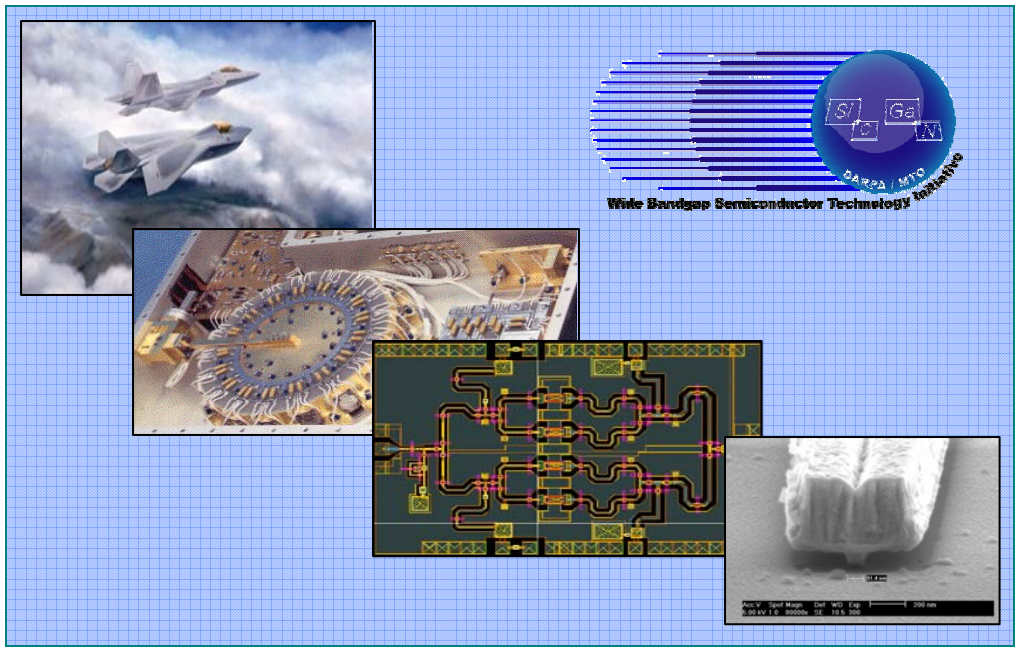
TIFT
(THz)



MIATA
(mm-Wave)



High Frequency Semiconductor Electronics Technology

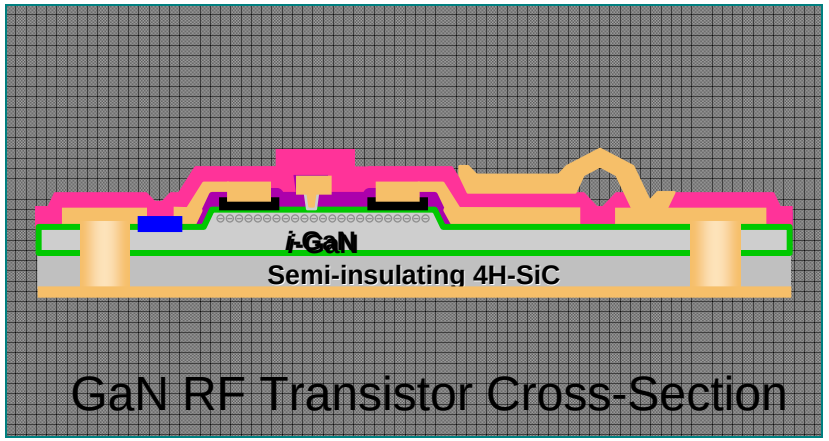


Exploiting materials to achieve reliable, high performance devices and MMICs with

- **higher power**
- **higher efficiency & bandwidth**
- **superior thermal performance**

Achieve rapid insertion into DoD RF systems

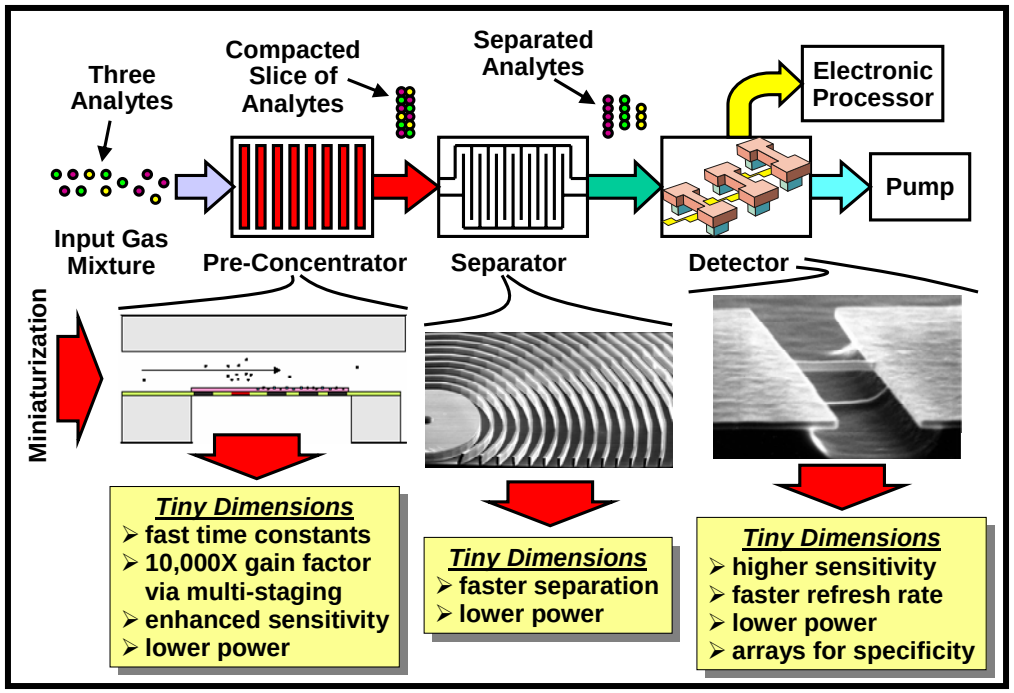
Revolutionizing RF systems performance through increases in solid state amplifier power, efficiency, linearity, noise figure, and robustness



GaN RF Transistor Cross-Section

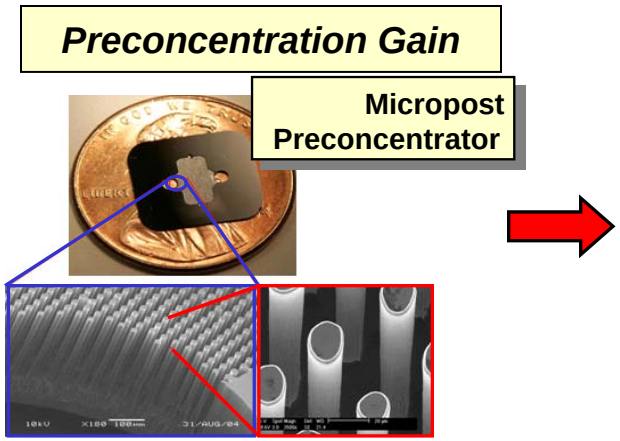
The Future of RF Electronics for Radar, EW, and Comms

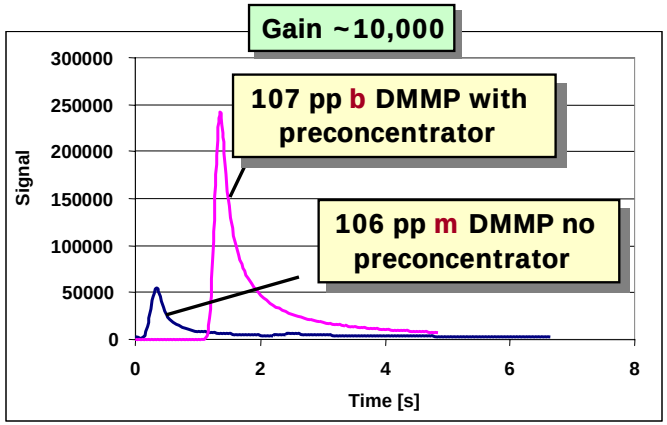
Chip Scale Gas Analyzers (MGA)



Remote detection of chemical agents via tiny, ultra-low power, fast, chip-scale gas analyzers that greatly reduce the incidence of false positives

- **Achieve 4 sec analysis time in <2 cc**
- **Minimum detectable signal < 1 ppt**
- **Energy per analysis < 1 Joule**

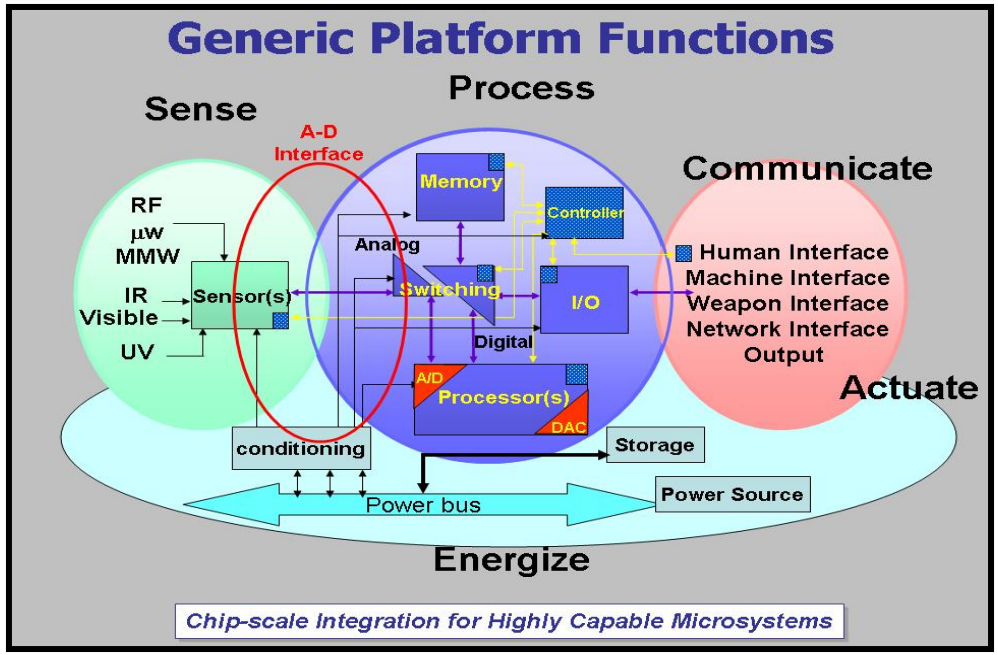




Gold Standard Chemical Gas Analyzer in a Match Box

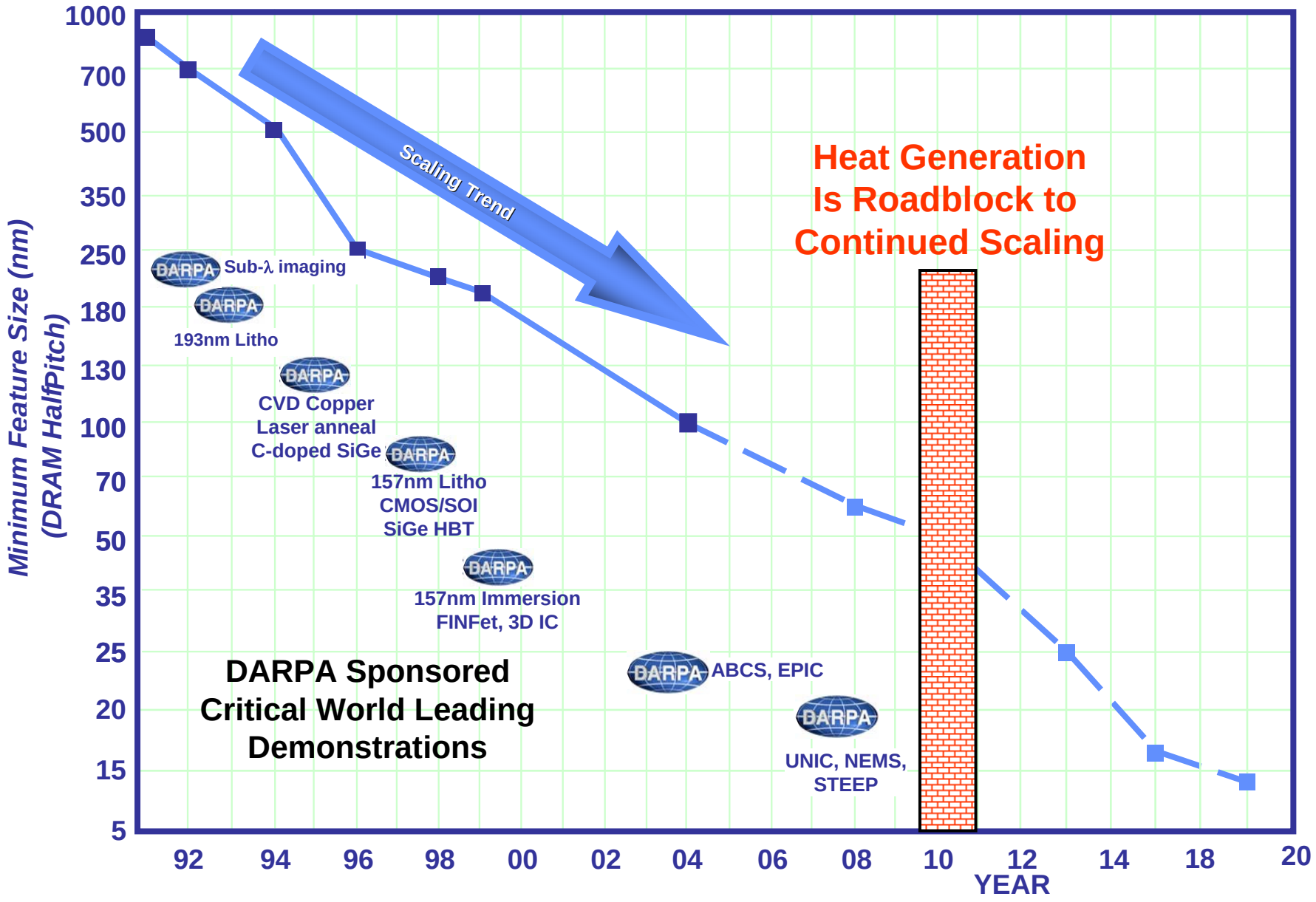
Opportunities

Microsystems Technology Advances
Enable Future ICONS



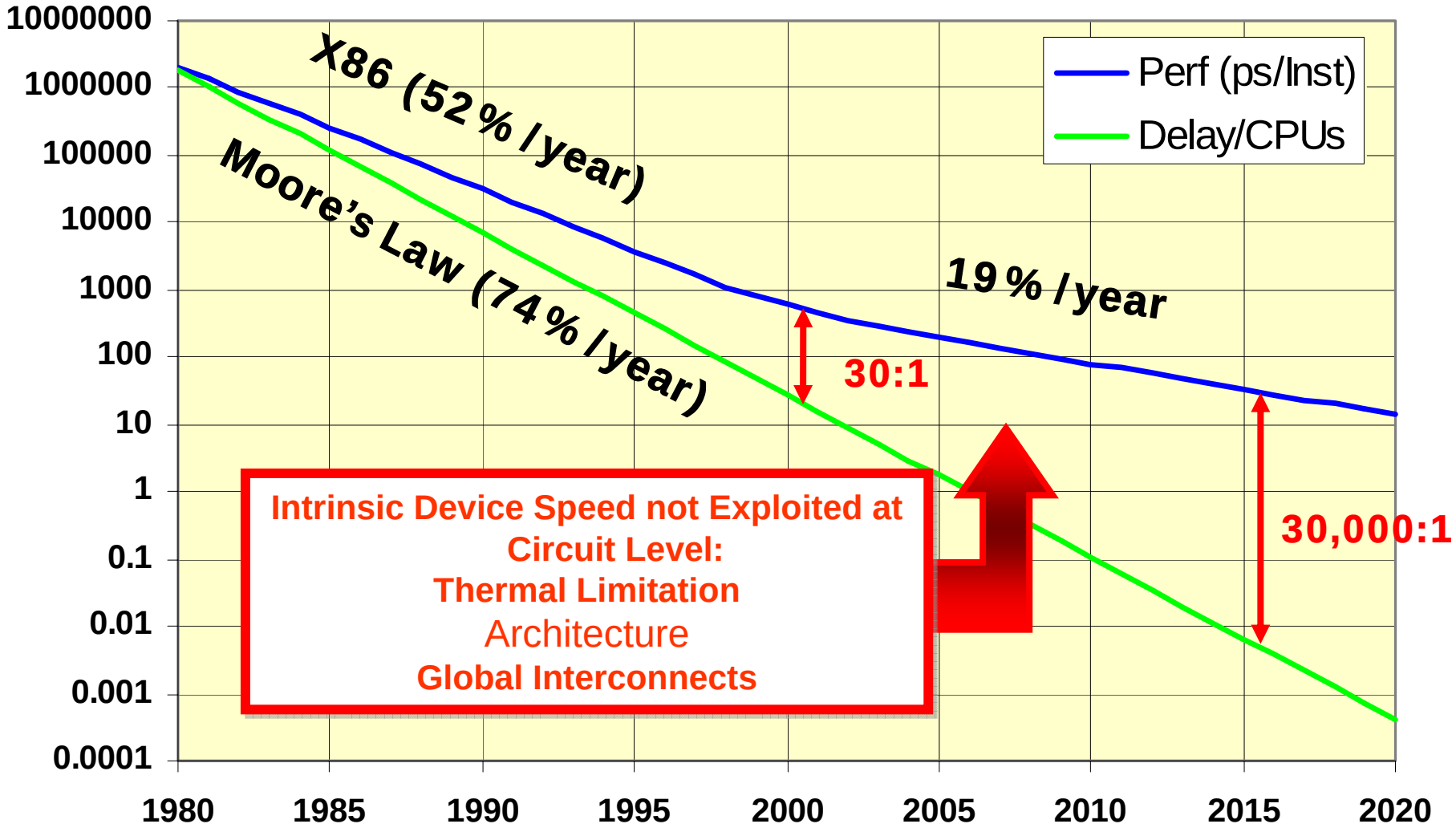
- Sense
- **Process**
- Communicate
- Actuate
- Energize

Exploiting Moore's Law



Supercomputer on a Chip

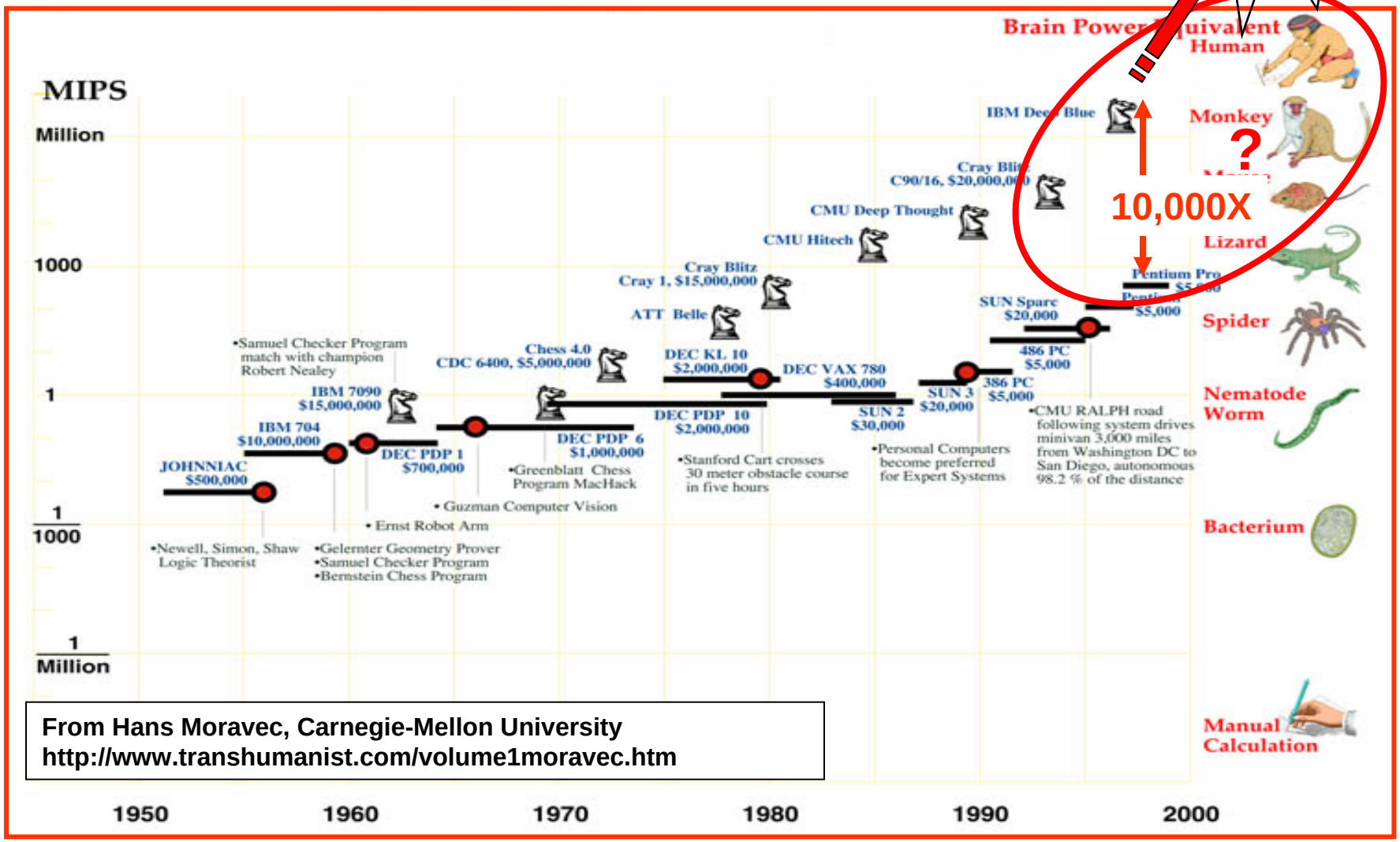
Intrinsic Transistor Performance versus Circuit Speed



Source: ISAT Summer 2001 Study- *Last Classical Computer*;
Prof. Bill Dally (Stanford U) Study Lead

Impact of Supercomputer on a Chip

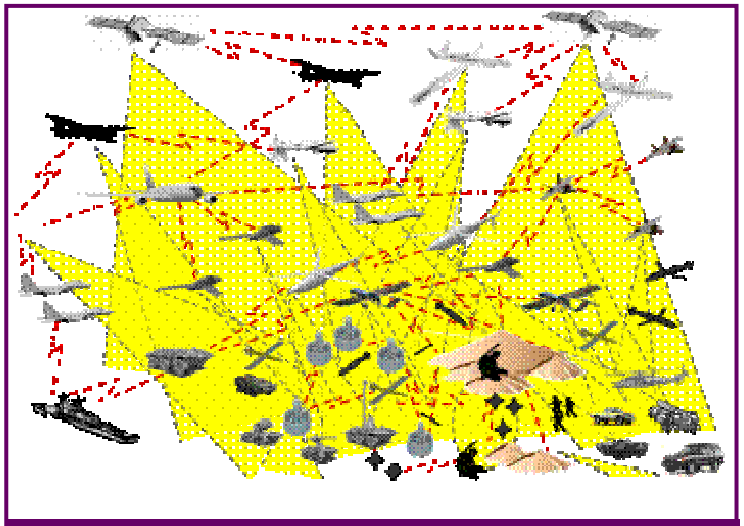
HPCS



From Hans Moravec, Carnegie-Mellon University
http://www.transhumanist.com/volume1moravec.htm

Cognitive Computing Challenges

Autonomous Robots



Massive Sensor Streams

Information Integration

Rapid Planning & Decision Making

Machine Translation

In Near Real Time

Global Autonomous Language Exploitation

Multiple media, sources and languages

Speech
Text

Streaming, changing huge volumes

GALE

- Speech translation
- Text translation
- Content distillation

Filtering, extraction, consolidation

Critical information reported in English

Alerts

Faster, more efficient decisions

Enable English speaking warfighters and decision-makers to directly absorb and analyze all incoming information in a timely manner regardless of language or medium

Distribution Statement "A" (Approved for Public Release, Distribution Unlimited

Continuous translation of formatted speech with content distillation

Real-time two way speech within a limited contextual domain

Phraselator to TRANSTAC

A Major Leap Forward

Handheld translation systems for spontaneous two-way speech communications under real world conditions

Phraselator-deployed today

Phraselator

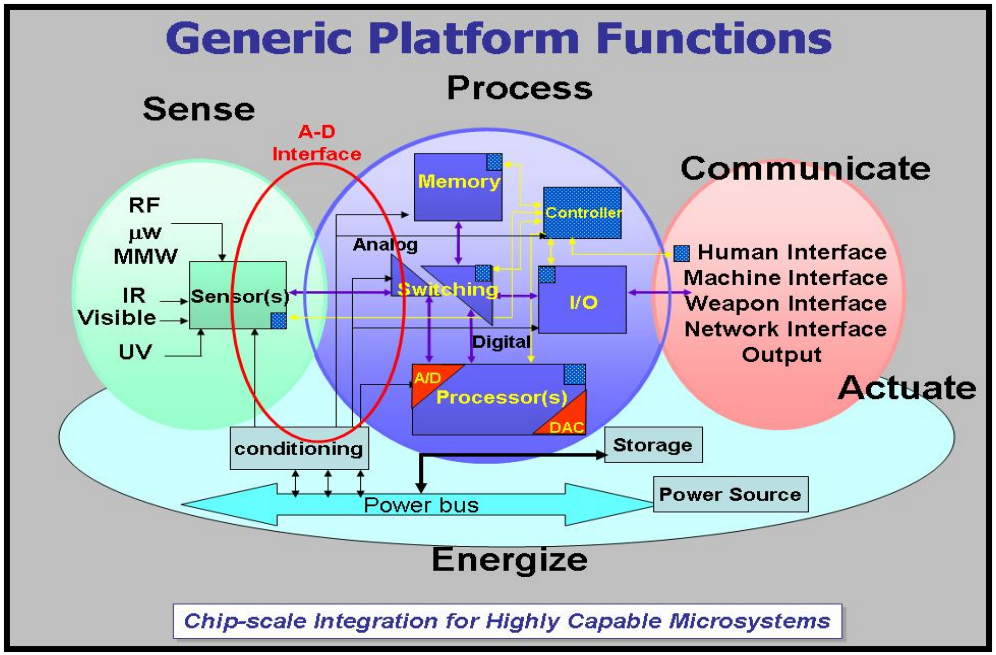
TRANSTAC-Tomorrow's Solution

- Begin with limited two-way system
- Constrain the domain
- Enhance performance through iterative testing - robustness to noise, context-driven ASR, etc.

Distribution Statement "A" (Approved for Public Release, Distribution Unlimited)

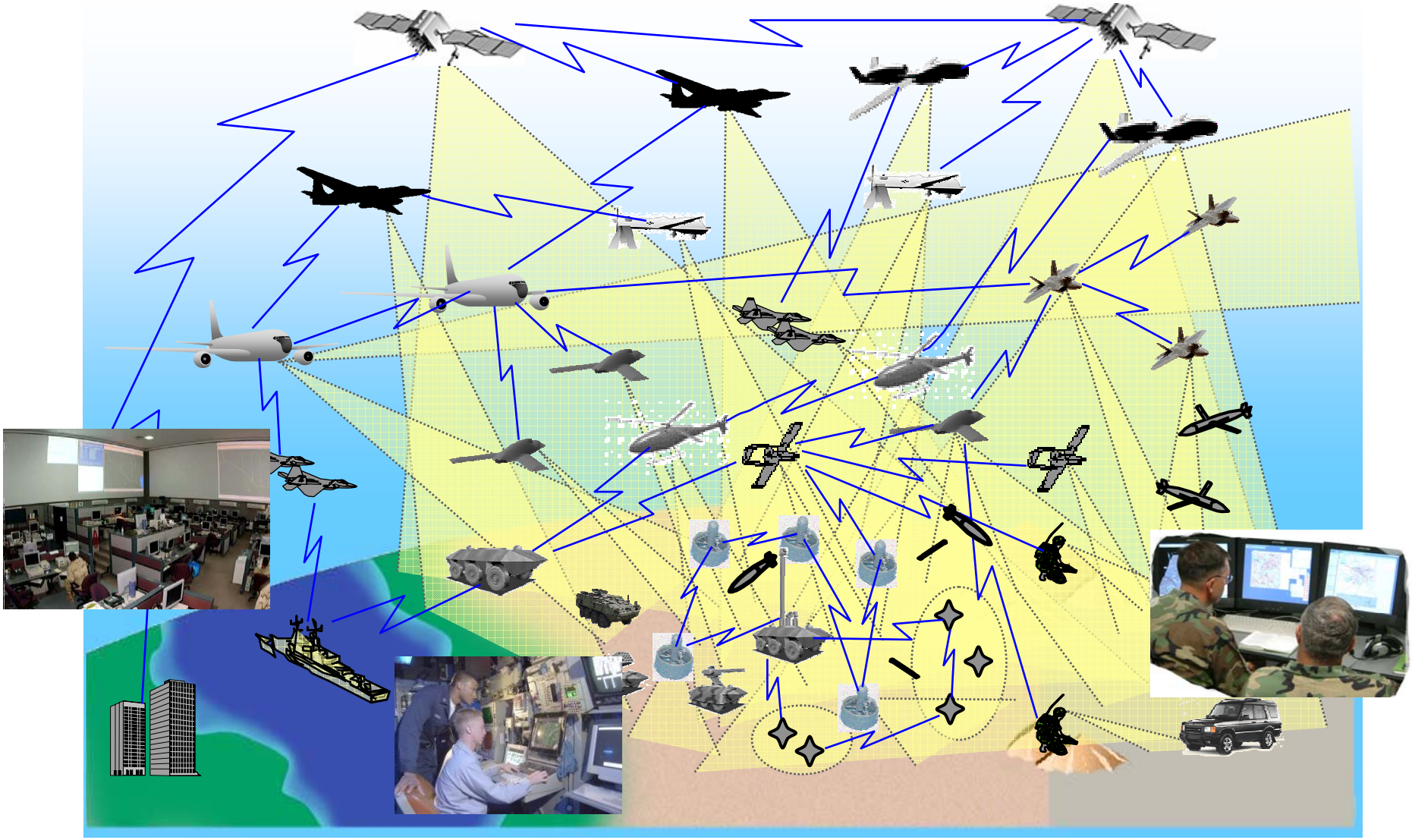
Opportunities

Microsystems Technology Advances
Enable Future ICONS



- Sense
- Process
- **Communicate**
- Actuate
- Energize

Network Centric Operations



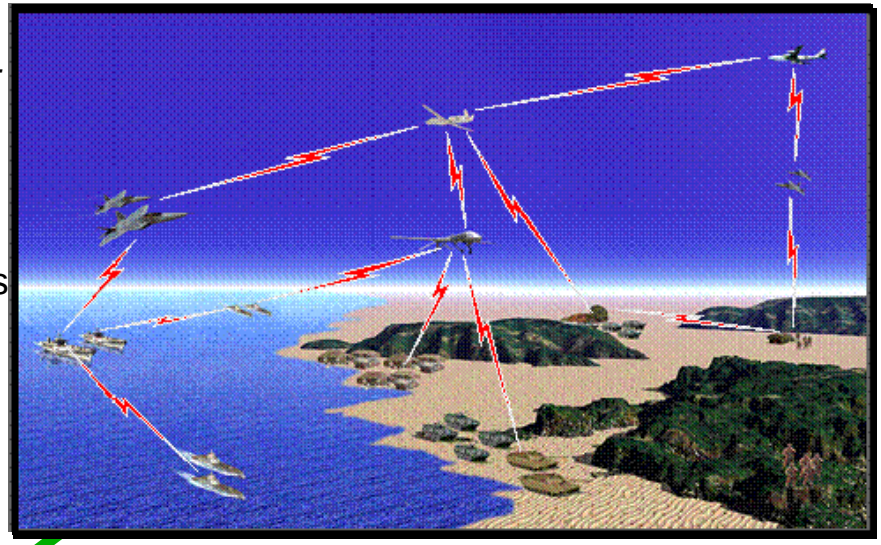
Military Net-Centric Communications

Challenges

1. Network Centric Enterprise

Strategic and operational level of deployment and warfare

- Cleared Personnel – TS/SCI
- Links air, ground and naval campaigns
- Engages by operational maneuver and strategic strikes
- Provides information, resources, and sustainment connectivity
- Large C4ISR backbone and infrastructure
  - Rides on GIG and Extensions
  - Can leverage commercial info systems
  - IPv6 early adopter
  - Susceptible to many IA threats



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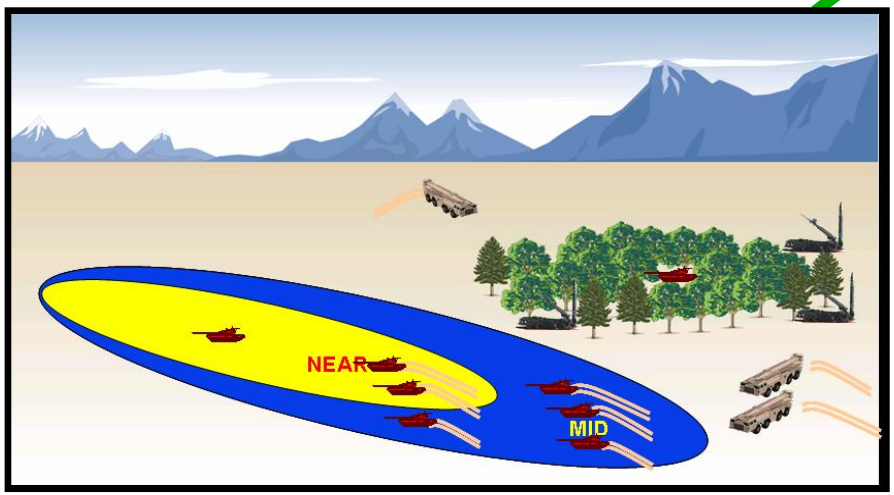
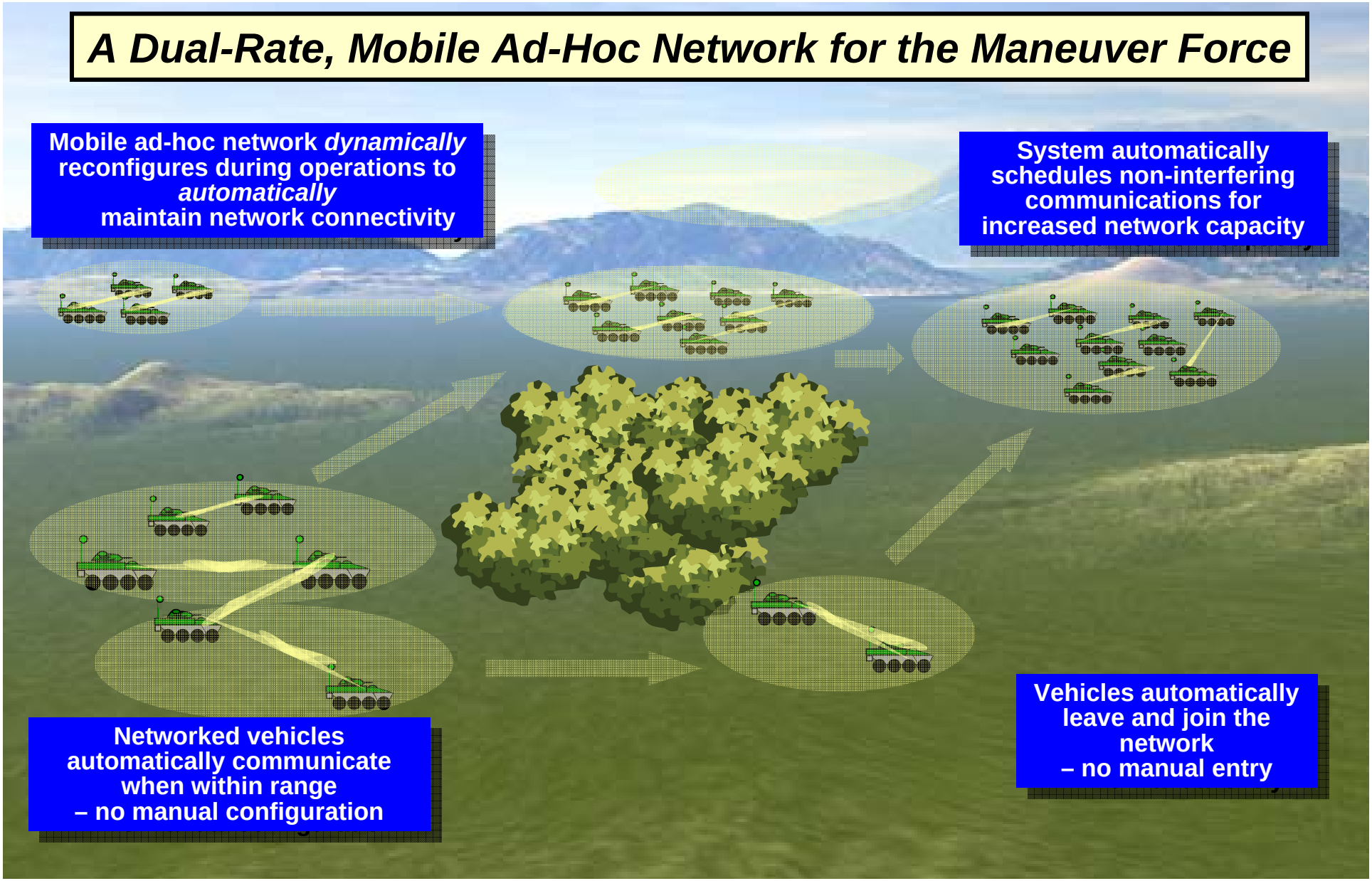


2. Network Centric Warfare

Tactical level of deployment and warfare

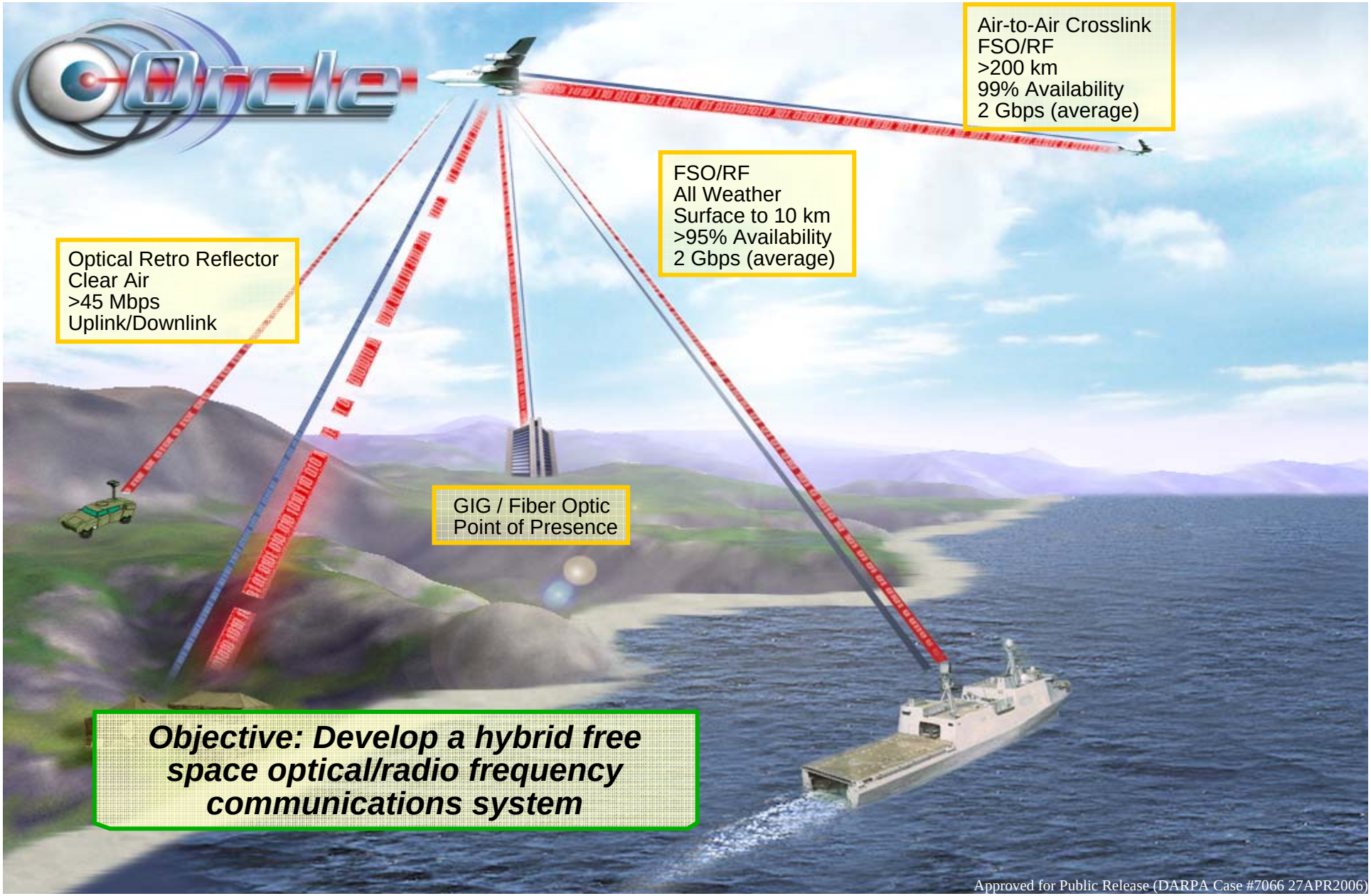
- Uncleared Personnel
- Links effects to targets
- Engages directly with the enemy
- Must be agile, adaptive and versatile
- Minimal, “portable” C4ISR infrastructure
  - Rides on tactical communications
  - Requires LPD/LPI transmission security
  - NCW weapons susceptible to IA attack

Networked Wireless Communications



Optical & RF Combined Link Experiment

Links to forces fixed and on the move

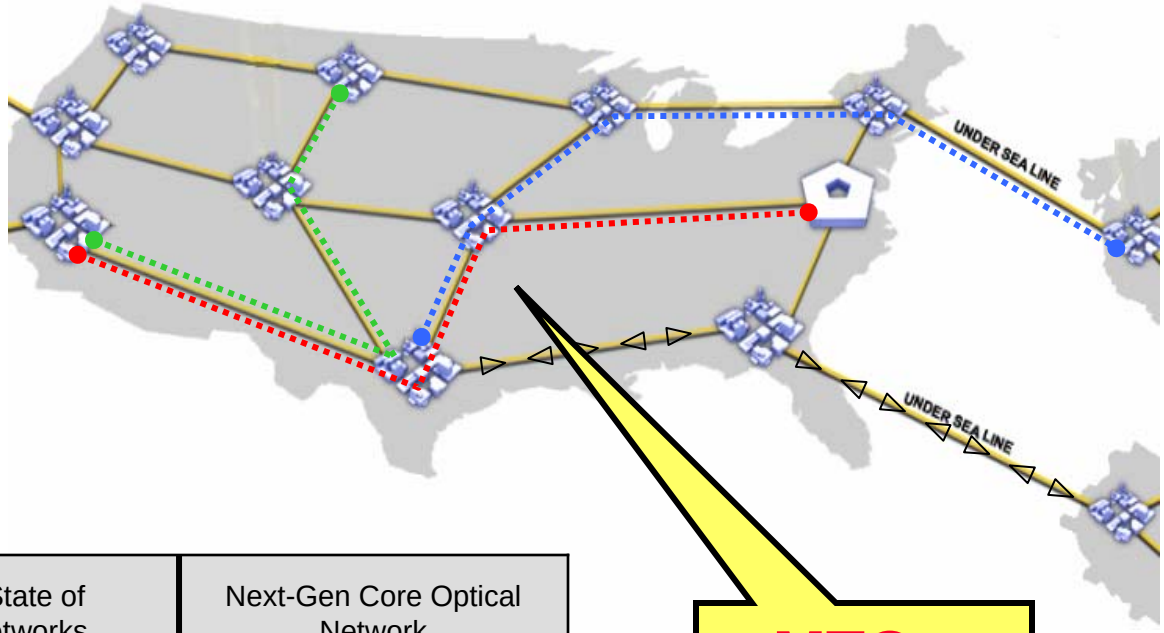


Approved for Public Release (DARPA Case #7066 27APR2006)

Next Generation Core Optical Networks

Goal: Increased Optical Network Throughput with Reduced Latency & Cost

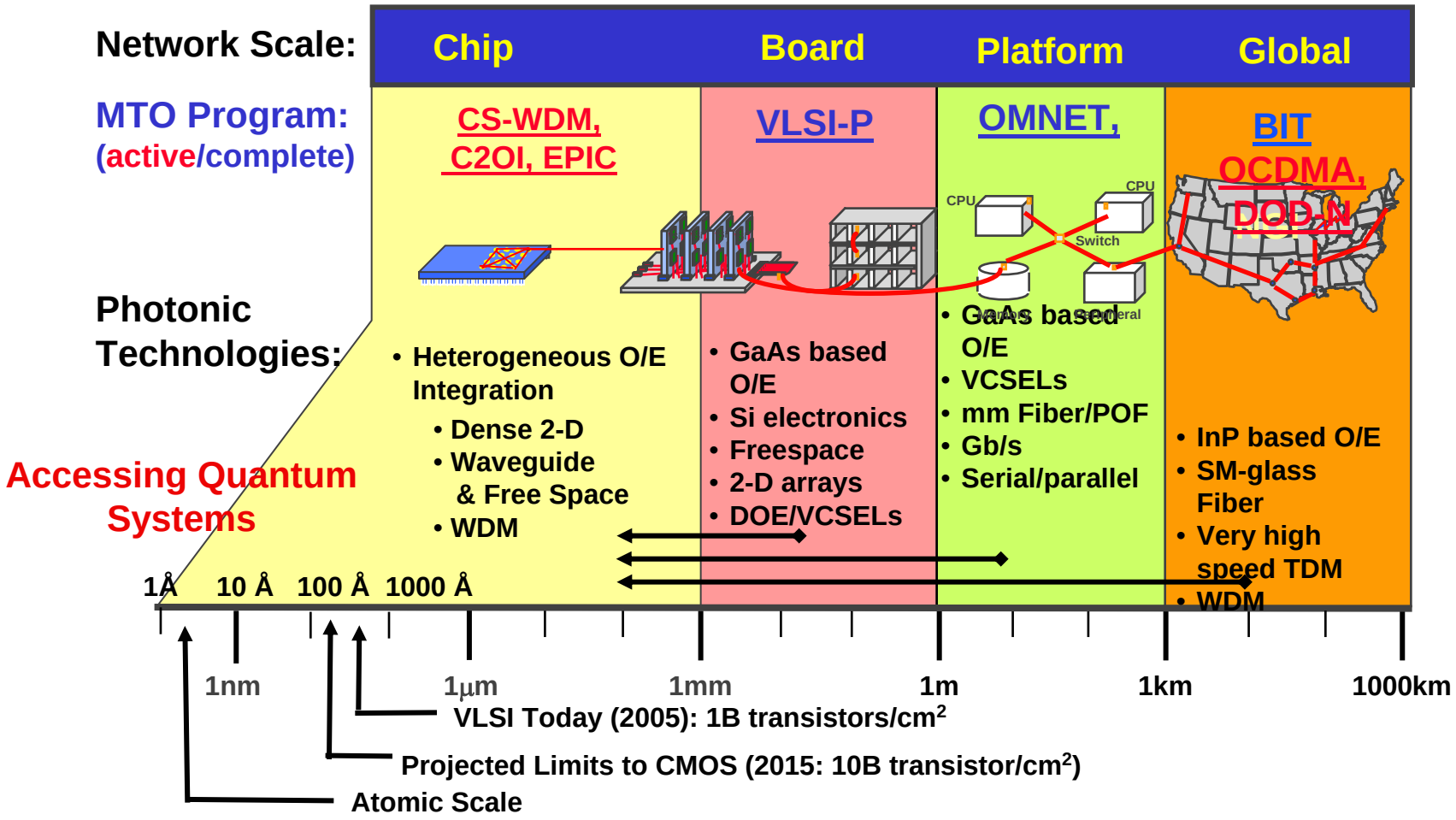
1. Ultra-High-Capacity, Long-Reach Transmission
2. All-Optical Switching and Circuit-Based Grooming
3. All-Optical Bursts or Flow Grooming in Edge Networks
4. Network Control and Management



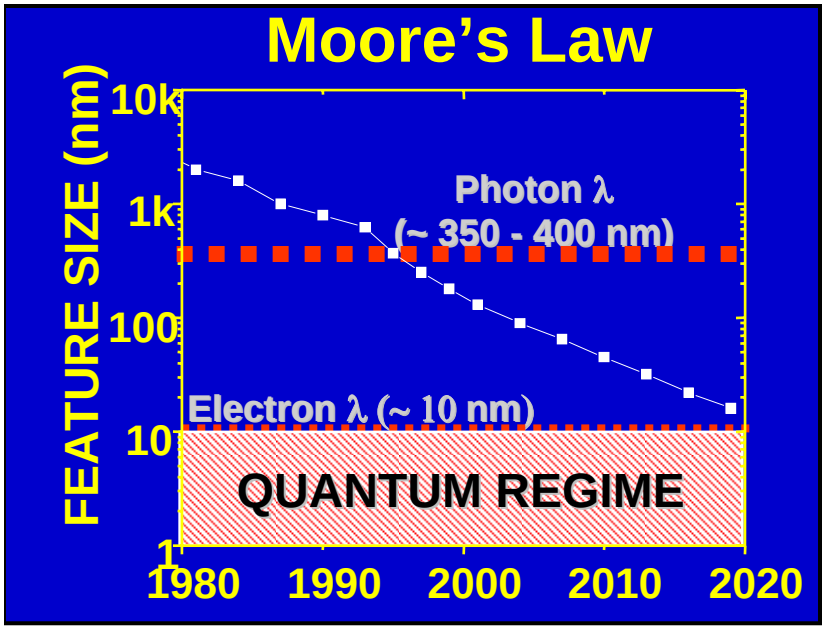
Network Requirement	Today's State of the Art Networks	Next-Gen Core Optical Network
Aggregate Capacity	10 Tb/s	100 Tb/s
Maximum Fiber Capacity	1.6 Tb/s	16 Tb/s
Bit Rate per Wavelength	10 to 40 Gb/s	40 to 160 Gb/s
Speed of Provisioning	Minutes to Hours	< 100 msec
Speed of Restoration	Seconds to Minutes	< 100 msec
Speed of Protection	50-200 msec	< 50 msec

Approved for Public Release (DARPA Case #7528 21JUL2006)

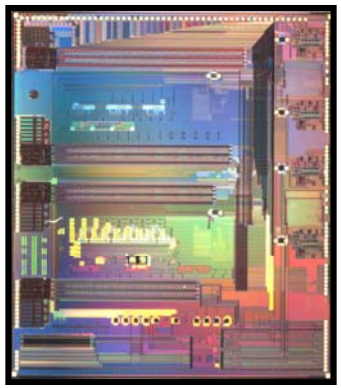
Photonic Data Links



Electronic & Photonic Integrated Circuits on Silicon



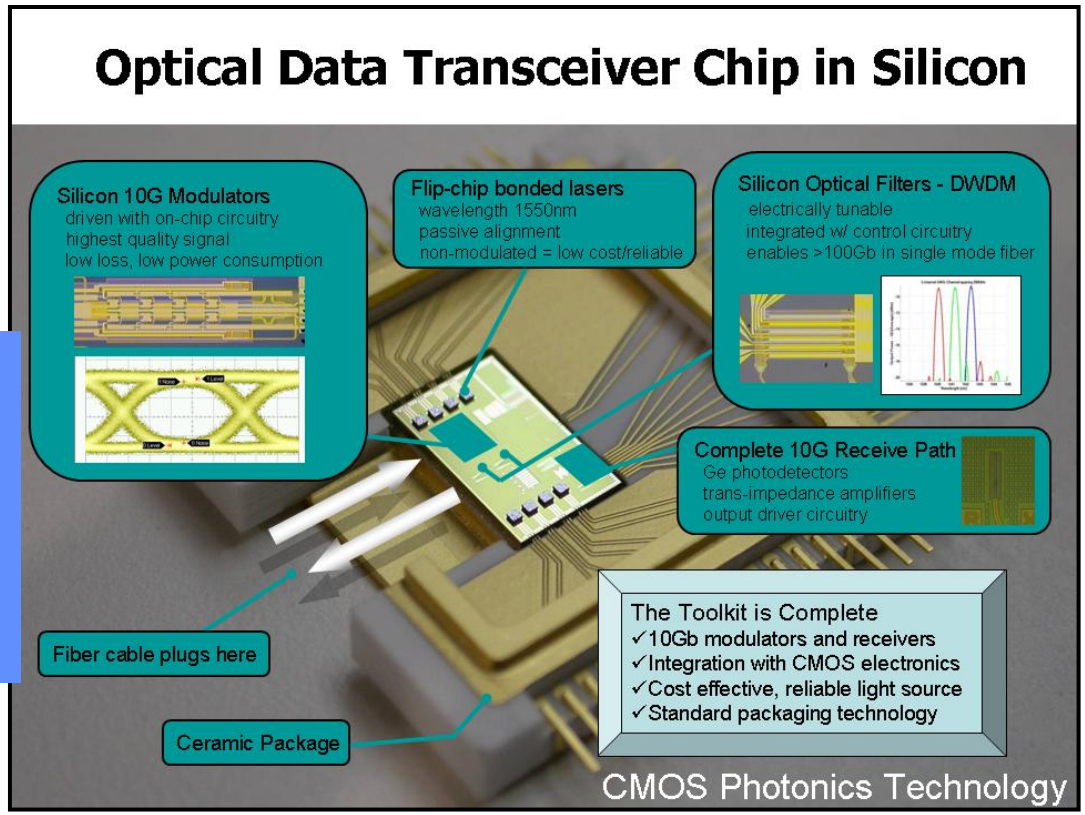
Integration of photonic functions with standard high performance CMOS electronics and fabricated in a standard CMOS foundry



8.02 mm x 9.17 mm die

20 Gb/s Transceiver
4 λ x 5 Gb/s into single fiber

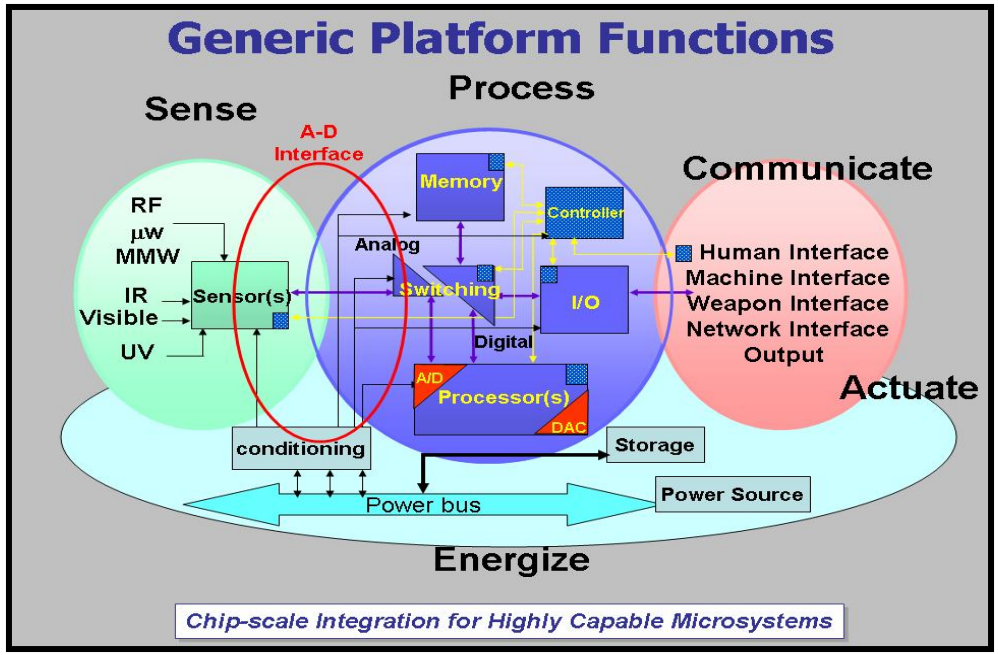
>100 photonic devices + > 5,000 electronic devices



Seamless Interface between Photonics and Electronics

Opportunities

Microsystems Technology Advances
Enable Future ICONS



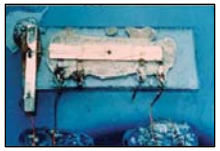
- Sense
- Process
- Communicate
- **Actuate**
- Energize

Actuate

Creating the MEMS Frontier

NanoElectroMechanical Systems

The First IC (Fairchild)

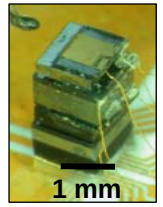


Pressure Sensor (Honeywell)

Si Pressure Sensor (Motorola)

SFB Pressure Sensor (NovaSensor)

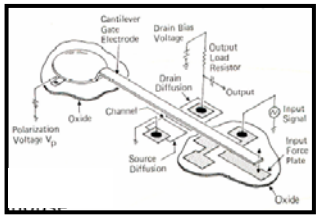
Chip Scale Atomic Clock



CSAC

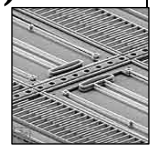
1950 1960 1970 1980 1990 2000 2010

Resonant Gate Transistor (Nathanson, Westinghouse)

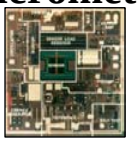


PolySi Micromotor (Tai, Muller)

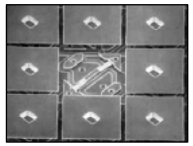
PolySi Comb Drive (Tang, Howe)



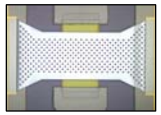
ADXL Accelerometer



DMD (TI)



RF MEMS



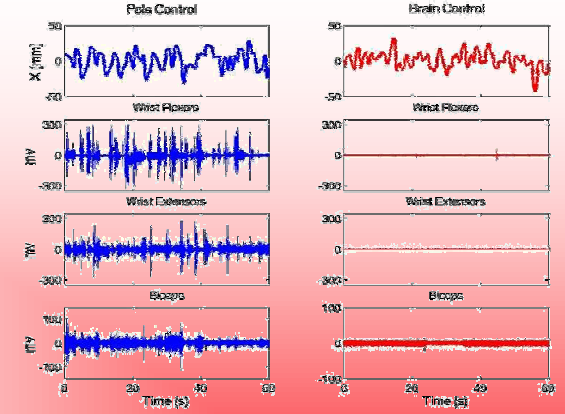
Fabrication plus Basic Sensors

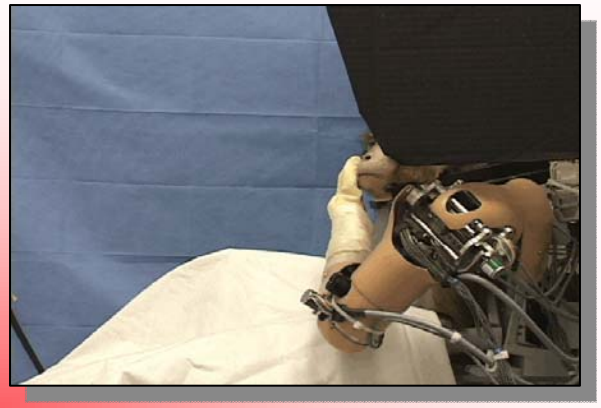
Surface Micromachined Sensors, RF-MEMS

Modified from a slide from
YC Tai, Caltech

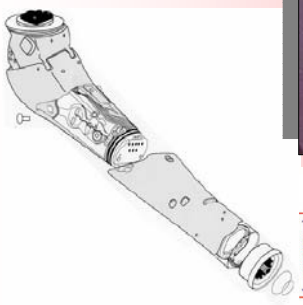
Revolutionizing Prosthetics

Understanding the Language of the Brain





State of the Art: Utah arm



Neurally Integrated

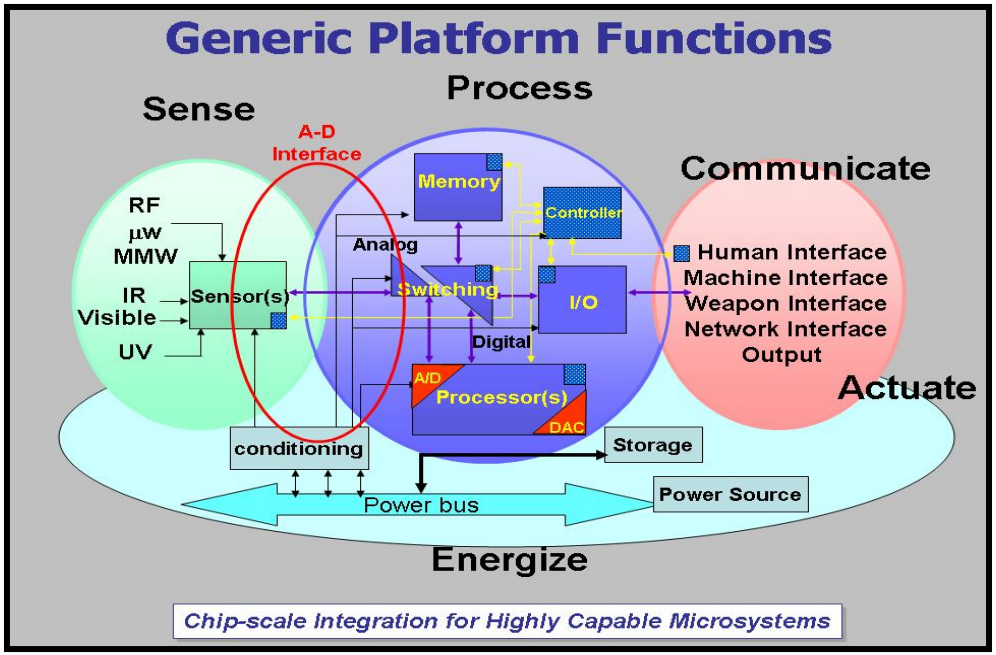
Mechanically Superior

- **Closed loop nervous system integration**
- **Full DOF, range-of-motion**
- **Proportional tactile & force receptors**
- **Human-like endurance and actuation**

Fully integrated limb replacements

Opportunities

Microsystems Technology Advances
Enable Future ICONS

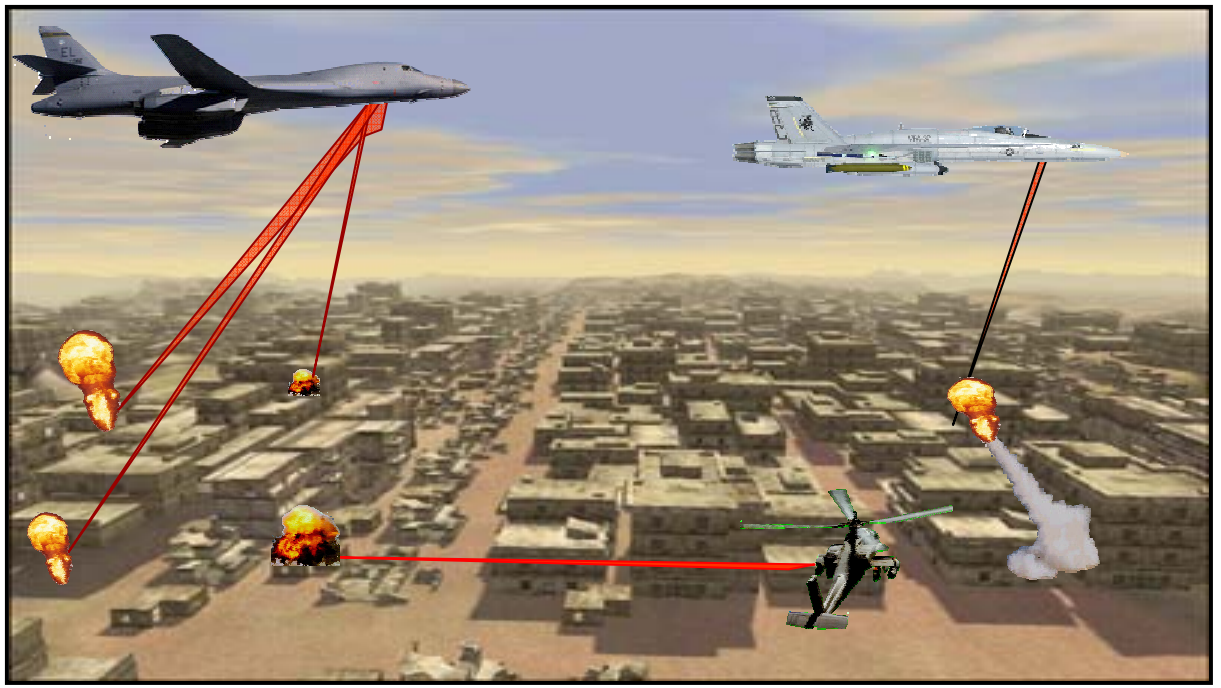


- Sense
- Process
- Communicate
- Actuate
- **Energize**

High Energy Liquid Laser Area Defense System (HELLADS)

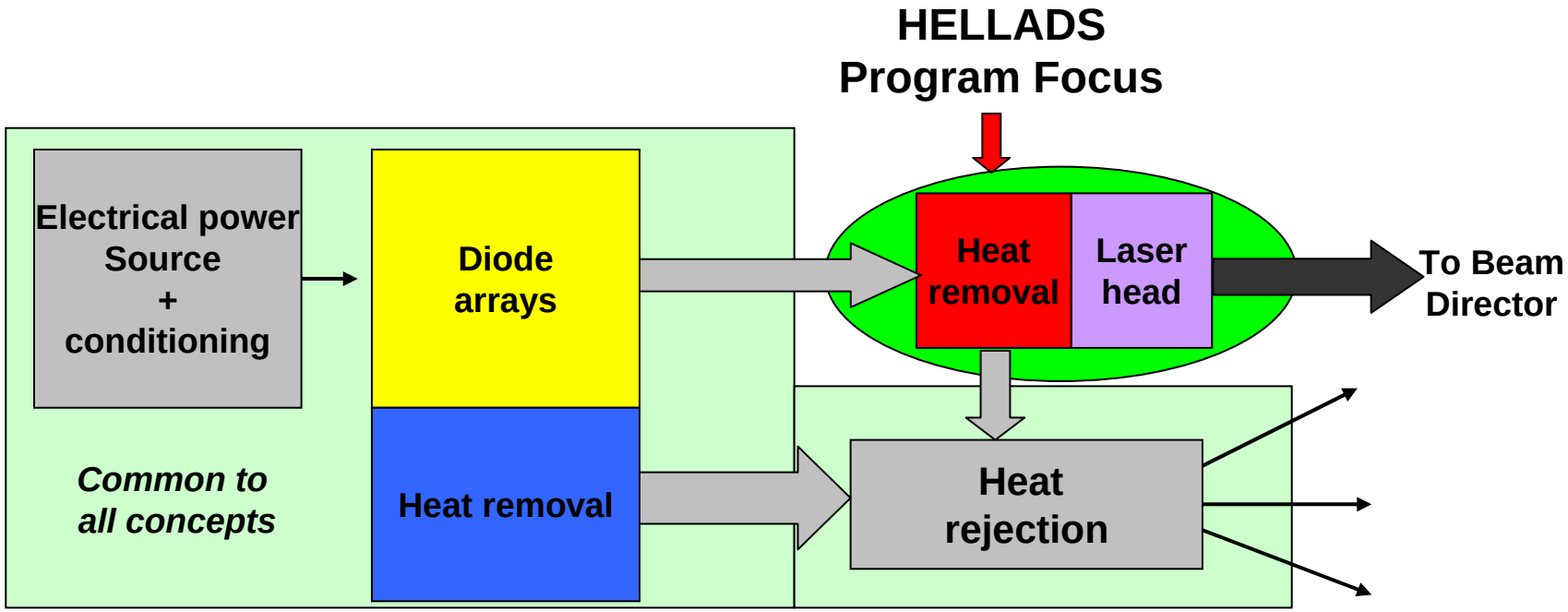
Offensive Targets
- Air defense systems
- Aircraft

Defensive Targets
- Cruise missiles
- Aircraft
- UAVs
- Low-altitude missiles
- SAMs



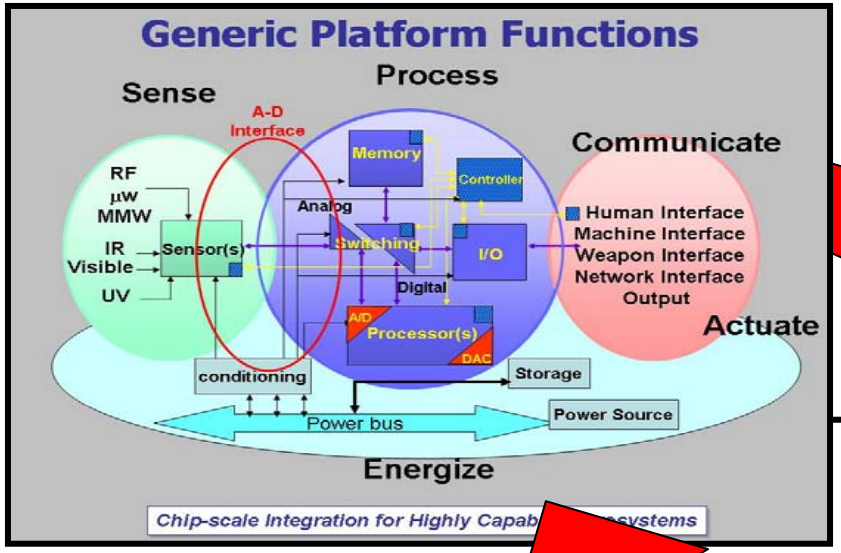
- *Novel Design That Combines the Energy Density of a Solid State Laser with the Improved Thermal Management Qualities of a Liquid Laser*
- *System Goals: 150 kW Laser Output, 5 kg/kW*
- *Enables Laser Weapon Systems Integration with Tactical Platforms*

All Diode-Pumped Lasers Have the Same Basic Components and Issues



Efficiency, power supply, thermal management and beam quality

Opportunities

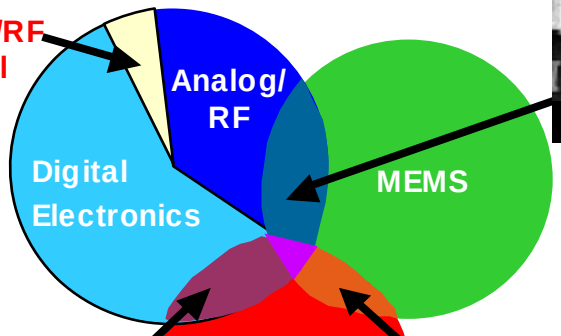


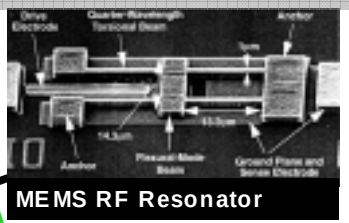
Applications Create Challenges

Innovations Create Capabilities

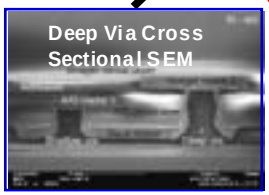
Core Technologies

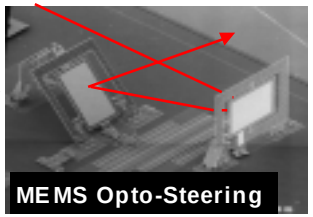
Digital-Analog/RF Mixed Signal



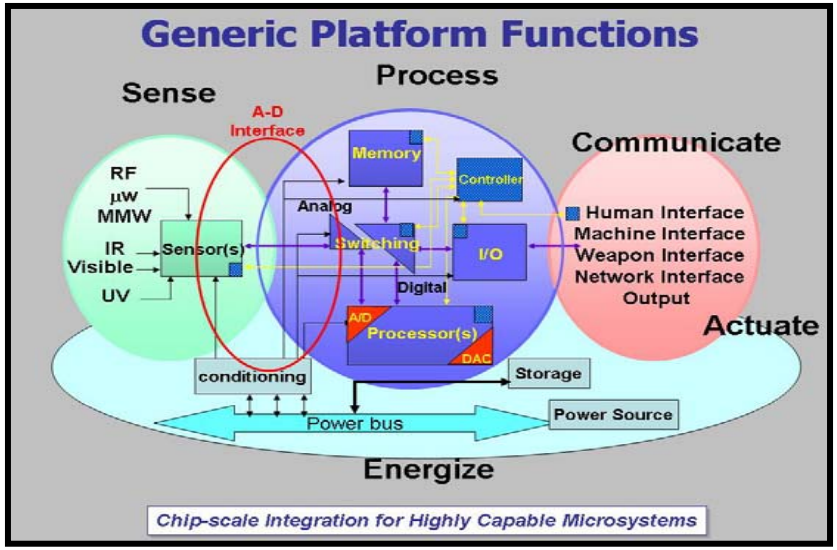

MEMS RF Resonator


A/D W afer
Imager W afer




MEMS Opto-Steering

Future Challenges



Sensing

- Single photon detection over SW/MW/LW IR
- Room temperature broadband sensing
- Create chip-scale hyperspectral sensing
- Small aperature mm wave/THz imager
- Subwavelength-size pixel focal planes

Processing

- Eliminate thermal dissipation road block
- Eliminate data throughput and memory access bottleneck
- Overcome the growing complexity in circuit design
- Theoretical limit analog to digital converters

Communication

- Complete chip scale radios
- Reduced latency
- “internet over RF”
- mm-wave communications
- Coherent optical communications

Actuation

- Chip scale avionics
- Universal MEMS packaging
- Chip-scale RADAR
- Ultra-stable, lower power timing devices
- Tunable directionality antennas
- Miniature GPS systems
- Micro-scale gas and liquid analyzer

Energize

- Laser diode bar lifetime and reliability
- Diffraction-limited, coherent high-power diode laser arrays
- Smart power management
- Long endurance micro-power generation

DARPA

DARPA's Industry Outreach

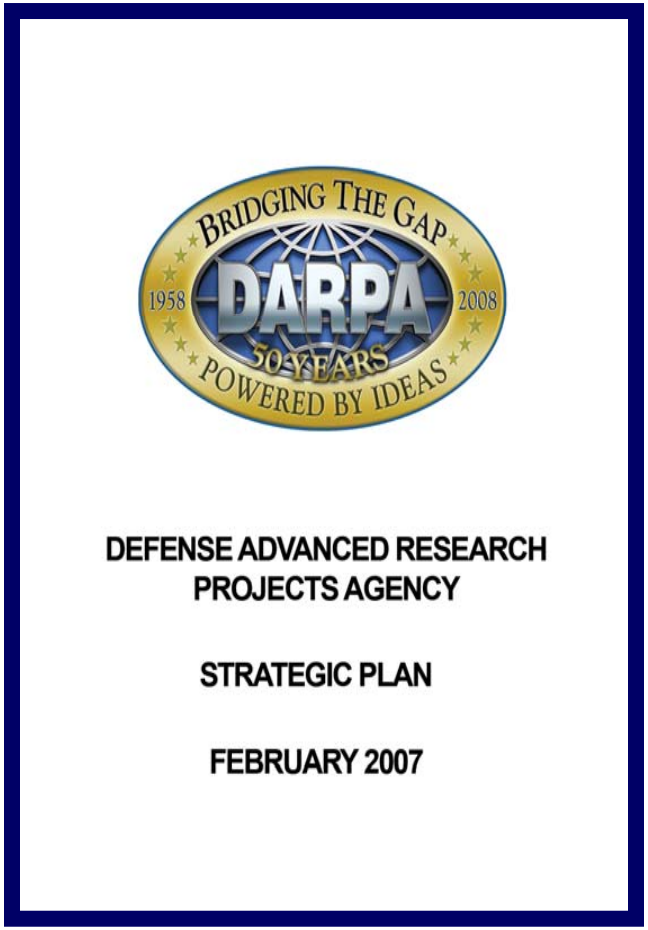
Always Interested in Innovative Ideas

- **For information on current solicitations & doing business with DARPA access**

  www.darpa.mil

- **Or, talk to a DARPA Program Manager**

- **Or, attend DARPATech 2007**



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